

BEYOND ENGAGEMENT: MEANINGFUL RELATIONSHIPS AMONG EXPERTS AND  
AUDIENCES IN THE PERFORMING ARTS AND SCIENCES

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This dissertation investigates the ways artists and scientists work together and the ways they think about audiences. Each of the three cases bring together collaborators from diverse fields to develop live performances and presentations. Two of these cases focus on art/science collaborations, and the third focuses on audience participation. Through close analysis of these cases, I examine collaboration between artists and scientists, the relationship between audiences and experts, and the way these two relationships complicate each other.

The first two cases were art/science collaborations in which I was a participant observer. The first, *Dance of Scales*, was a multimedia event featuring dance and physics. In the second case, I worked with another group of artists and scientists to create *Emergence*, a play developed to further explore scientific research through narrative and participatory experiences. The aim of these projects was to closely examine the collaborative process between artists and scientists, but the studies led to interesting questions about the nature of the relationships developed between presenters and audiences, the subject of the third case. This case investigated questions about the relationship between audiences and experts through the development of an audience participation system. The system, called Frontstage, was tested in a museum context, at a performance, and at a conference for undergraduate engineering students. Each of these uses revealed different

aspects of the program, as well as the relationship between the presenters and the audiences in these varied contexts.

These three cases led me to focus on the relationships between expression, explanation, interpretation, and understanding, and to identify the ways these relationships function in different styles of events. Through discussions between artists and scientists involved in the project, I found that explanation can be characterized a constrained form of expression and that, though not a perfect analogy, understanding can be characterized as the way audiences interpret constrained expressions. I also found that understanding could lead to opportunities for richer interpretation. These ways of conceptualizing expression and interpretation led me to question the paradigmatic model of science communication, public engagement, and to begin to think about how scholars and practitioners might rethink the way we approach science communication.

## **BIOGRAPHICAL SKETCH**

Megan Halpern's research interests include collaboration in art, science, and design; human computer interaction design; and public engagement with science. Her recent work has focused on the relationship between experts and audiences in a variety of contexts in both the performing arts and sciences. Megan has been designing mobile applications for Cornell's Interaction Design Lab for the past five years. Her work includes Frontstage, an audience participation system; SunDial, a science-themed geocaching adventure; and MoBoogie, a music-based app for creative expression through movement. Megan is also an experienced science theater producer and the co-founder of Redshift Productions, a company that works with artists and scientists to develop performances as science outreach.

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## **PART I**

### **CHAPTER 1: INTRODUCTION**

#### **An Experiment in Improvisation**

My work as a researcher began long before I knew I was conducting research. It began in 2004 in a small rehearsal space in New York, where I (along with my partner and a few likeminded friends) assembled a handful of improvisation actors and began creating science study guides for them. Our goal was to create, through improvisation, a devised script about science. We were not clear what kind of science, or what themes or style the performance would embrace, nor had we committed ourselves to a specific aesthetic. In retrospect, it seems we had left the idea too wide open to succeed. But, here we were, with a room full of experts in performing, but no experts in any field of science, and we were hoping to create a show that would get scientists' stamp of approval as "accurate" and "true" (these were much less complicated words to me at that point). And why couldn't we lay people create a show about science? My partner and I had done so twice. The first time, we created a live music and dance performance ostensibly about Aristotle's four elements that drew on modern understandings of geology and geophysics. Luckily, our choreographers had been as enthusiastic about these subjects as we were. We had also written a rock opera about the Galileo mission to Jupiter that used images and animations created by NASA's Jet Propulsion Lab and the Galileo orbiter. Now, we were turning to comedy, and we were opening up the creative process by embracing devised theater.<sup>1</sup>

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<sup>1</sup> Devised theatre is a process by which a group of collaborators (or an individual) use improvisation and other techniques to create a performance. For more information on the history and practice, see (Heddon & Milling, 2006; Oddey, 1994).

After trying and failing to explain quantum physics to ourselves and to this group of actors, and also trying and failing to recreate simple physics experiments in the rehearsal room, we realized that even with dense printouts from websites and copied sections of books by Stephen Hawking, we could not navigate the complex waters of science on our own. We needed an expert in the room. I sent blanket emails to physics, chemistry, and biology departments at all of the major universities in New York, and, I got a few responses. Several weeks later, our first artist/scientist collaboration began, as one might imagine, with a scientist coming in and delivering a brief lecture on his work, at which point, the improv actors worked together to come up with sketches that they thought represented what they had just learned from the scientist. The scientist corrected them. They tried again. The process was fun, but frustrating. What were we doing wrong? We held what we called a Collaboratorium, an event we hoped would be a space for development of new approaches to art/science collaboration, to open this process up to a broader group of collaborators. We replicated what we had done in these rehearsals with scientists in front of a group of people from various backgrounds in science, science education, and theatre, and asked them to comment on the process. Our first revelation came when a physicist said, “You got to learn about what I do, but I didn’t get to learn anything about what you all do!”

This was our Eureka! in the bathtub, so to speak. Our next rehearsal with a scientist began with a warm up in which the scientist participated. We had him play some improv games with us, and we asked him questions about his work. This improved the experience drastically. And we realized, the model of the science lecture followed by the artists’ exploration may have been the most obvious, but it was not the strongest model. We began to develop new warm ups and games that incorporate the scientist’s ideas and insights and we included them in activities designed to

pull them out of their comfort zones. One such game, which we called PowerPoint, could be replicated with almost any scientist to consistently humorous ends, but it was humorous because it touched something deeply embedded in scientific culture. We noticed early in the process that most of the scientists who came to our rehearsals had a PowerPoint, or at least a group of images and formulae on their computers that they would show us as they explained their work. We took their computers away and asked them to speak as if they had their PowerPoint slides, but the actors would replace the slides, acting, as best they could, the words of the scientists. This is modeled after an old improv favorite, slide show, in which the improv actors would ask audiences for a location and one would present the “slide show” of their trip to said location while the others acted as the slides. While the game was fun, hilarity ensued, and everyone got better at understanding and working with one another, PowerPoint revealed that some scientists simply could not part with their PowerPoint slides. Even when they did, there were still many barriers to mutual understanding between the scientists and actors, and it was these barriers that often sparked the humor. These were my first observations of artist/scientist collaborations, and they eventually led me to think my role as a producer was not enough, I wanted to extend that role to conduct research about these fascinating collaborations. This is where my career as an academic began.

If this dissertation begins with the intersection of art and science, it ends with the intersection of expert and audience. The intractable problem of the chasm between art and science seems to pale in comparison to the chasm between experts and the public, especially in the sciences, and this separation is far more present in the minds of both the public and the experts reaching out, or failing to reach out to them. It is written in the stories about climate change denial and anti

vaccination movements; the hostility toward publics who fail to embrace scientific knowledge and in the way publics dismiss scientists as intellectual snobs. But it is also written in the continuing way in which the cultural elite proclaim the imminent death of theatre or the lack of understanding of modern dance or modern art. A different story is written in the studies that show movies like *The Day After Tomorrow*, however inaccurate or unscientific they are, change public perceptions on climate change (Leiserowitz, 2004), and in studies that discuss “The CSI Effect,” or how television crime shows have affected the expectations of juries (Schweitzer & Saks, 2006; Shelton, Donald, & Barak, 2007). The relationships between artists and their publics vary widely, and they differ from those of scientists and publics. Neither *The Day After Tomorrow* nor *CSI* are considered high art, or even particularly excellent examples of their forms, so the art worlds to which they belong may take issue with these two examples as “art” per se. Nevertheless, the nuanced relationship between art, science, and the public in these instances reveals a deep connection between the art/science relationship and the relationship between experts and publics.

### **“Non Public Area/Scientists at work”**

I took this photograph while on vacation in 2011. The photo is taken from outside the “Project Lab” at the California Academy of Sciences in San Francisco. As of April 2014, their website describes the Project Lab as “a multi-user, state-of-art lab outfitted with equipment needed for researchers to prepare, process, and catalogue specimens from the Academy’s research collections” (California Academy of Sciences, n.d.). The same webpage, found in the Exhibits section of the website, says that the goal of the Lab is “to create a sense of transparency and

connectedness between the Academy research departments and the public. This is a chance for the public to see what real science looks like, and for scientists to showcase their work on the public floor.”



***FIGURE 1: A photograph taken in 2011 front of the Project Lab, a working laboratory that serves as an exhibit at the California Academy of Sciences.***

To me, this photo illustrates very well the current best practice we scientists, science educators, and informal science educators have for communicating with the public about science: the Public Engagement with Science (PES) model. Public engagement comes on the heels of what we now call the deficit model, and replaces the public understanding of science (PUS) model for science communication because the creators of this model hope to create space for a two way conversation between scientists and publics in which communication moves both downstream and upstream. The model, while noble, is not without its tragic flaws, many of which are brought

to light in a recent special issue of *Public Understanding of Science*, a journal that played a large role in ushering in the era of engagement (Bauer, 2014; Guston, 2014; Jasanoff, 2014; Jia & Liu, 2014; Sturgis, 2014; Wynne, 2014). At the heart of each of these critiques and those that preceded them (Bauer, Allum, & Miller, 2007; Wynne, 2006) there is a serious question of attainability rather than a question of the quality of the idea of engagement. The aim of the lab as stated on the Cal Academy website, to create a sense of transparency and connectedness, reveals a drive for openness and two-way communication, but the sign warning the public to keep out, because this is where science happens, reveals a deeply embedded idea about the nature of scientific work and the real ability of the public to actively take part on equal footing with the scientists themselves. I want to approach this irony with earnestness rather than cynicism. Rather than doubt the sincerity of the museum staff as they developed and designed the lab as exhibit, or to lambast them for their obvious disregard for their own desire for connectedness with such an off-putting sign on a glass wall to designed to keep the public away from the valuable scientific specimens and data in the lab, I want to assert that the idea of engagement simply may not be attainable in the way the science communication scholars envisioned; that, as usual, the relationship between science and the public is, in a word, complicated.

Several factors impede what to me appears to be the naive optimism of the engagement model.

First, the power structures embedded in science social worlds make pure two way communication a challenge that only a few extremely talented and thoughtful experts can muster, and, second, the idea of engagement as it is presented to science communicators makes presumptions about the relationship publics wish to have with science that may not necessarily

be true. This question of what the public wants from their encounters with science leads me back to the art/science divide, and how both artist and scientists think about audience.

This question of audience is one place where the art/science relationship and the public/expert relationship meet, and at this intersection, I believe we can find illumination about both. This dissertation is my attempt to piece together a new way of approaching both relationships that will benefit both researchers and practitioners in these areas. The foundation of new approaches to art/science collaboration are documented in some of my previous work (Halpern, 2012; Halpern, Erickson, Forlano, & Gay, 2013). These past collaborative endeavors, as well as those discussed in this dissertation are built on a set of design principles and adapted to collaborative creative processes. In the case studies, I will describe the methods by which I engaged several artists and one very prolific scientist in collaborations to produce two new performances, and I will describe the results of these collaborations. I will also examine the relationship between experts and audiences in these two performances as well as a third case, an audience participation system that was used in a variety of artistic and scientific endeavors. To ground these cases in language that will help provide insight, I will turn to the current as well as historical discussions of art and science, including the two cultures debate, discussions of boundary work and social worlds, and the creation and use of boundary objects and similar artifacts that help individuals and groups navigate the boundaries and worlds within and around their collaborative work.

Each of the three cases discussed in this dissertation examine the relationship between live audiences and experts or presenters within different fields in the arts and sciences, some in collaborative projects between artists and scientists. The projects span several fields and

incorporate various methods related to participant observation, ethnography, and research through design. They are connected by the fact that they all deal, in some meaningful way, with the intersection of art and science, and with the idea of public engagement. The first case, described in Chapter 4, focuses on the development and performance of *Dance of Scales*, a dance performance by a physicist and choreographer. I used participant observation to learn firsthand how the artists and scientist with whom I developed the performance went about collaborating and thought about their audiences. I also conducted interviews with audience members to see how interpreted the performance. In Chapter 5, I describe the continued the use of participant observation and art as research methods to co-create and study *Emergence*, a theatrical performance developed by a group of artists and scientists. While the process and products were quite different, the aim of both of these pieces was to create performances that introduce current research in condensed matter physics. In Chapter 6, I describe the final case, a research through design project in which I built an audience participation system called Frontstage, that was used in several different scenarios, including a performance and a science lecture. Frontstage explores the relationship between expert and public across different disciplines by considering the relationship between presenter and audience in a variety of situations.

I developed *Dance of Scales* (DoS) with a physicist, a choreographer, a producer. This project was rooted in my background as a theatre professional, and drew on my experience as a theatre producer, science communicator, and researcher. The project itself was interdisciplinary and like my previous work in this area (Halpern, 2009; 2012; Halpern et al., 2013), examined the ways artists and scientists engage in positive boundary work and make use of boundary objects to collaborate with each other. *Dance of Scales* was part of a continued partnership between Itai and



Maren, a physicist and dancer/choreographer who first worked together during a previous project. The two of them envisioned a project that would integrate Maren's choreography with Itai's research by exploring the way things move at different length scales.

*Emergence* was also devised by scientists and artists. In this case, the production was a collaboration between a director, physicist, producer, me, and later a playwright as well.

*Emergence* focused on the way patterns emerge in local behaviors and how those patterns translate into global behaviors. For example, scientists may understand the way a single neuron behaves, and they may understand how thoughts work, but they have yet to bridge the two concepts. *Emergence* explored the work being done to understand that bridge. At the same time, *Emergence* was a story about a scientist who suffers from agoraphobia and has to learn to rely on her understanding of scientific phenomena to help her cope with aspects of her daily life. Though the project had similar roots, our approach was different, and the participants brought with them additional agendas. I sought to build on the knowledge generated by *Dance of Scales* and to further examine how audiences respond to such collaborations by conducting focus groups and interviewing audience members.

Frontstage, the final case discussed in this dissertation, builds on some of the themes that emerge in the first two, but takes a different approach. Frontstage is an audience participation system designed to work on iOS devices (iPods, iPhones, and iPads). The system was developed to create opportunities for audiences to participate in presentations and performances in a variety of ways in real time. Frontstage consists of several "modules" that create different interactive experiences. Audiences were given iPods (or intermediaries worked with them using the iPods)

and were able to use the different modules as different kinds of inputs. The presenters then displayed the information provided by the audiences on an iPad, which, in most cases, was projected during the presentation or performance. Frontstage was tested in the lab and in several smaller tests at a local science cabaret, and then was implemented in three diverse situations: A theatrical performance, a museum opening, and a presentation at a conference for undergraduate nanoscience researchers. The project examined relationships between publics and experts through their interactions with Frontstage. At the same time, the Frontstage project was also reflective of the growing interest in research through design, and a study in the relationships between designers, researchers, and users/participants. I approached Frontstage as a research question about how presenters conceptualize their relationship with audiences, but the work of answering this question came out of an attempt to develop an audience participation application.

In my analysis of these cases, I pay close attention to the relationships between art and science and between expert and public, with a particular eye toward the conceptualizations of public engagement discussed in Chapter 2. I also examine the boundary work inherent in the creative process. Though I began the first case study with the desire to make a contribution to knowledge about the intersection of art and science, by the time I reached the final case, I found there was much more to say about the intersection of expert and audience, and studying that intersection through the lens of art/science collaboration proved a valuable and novel way to understand experts and audiences. In both *Dance of Scales* and *Emergence*, I found that the disconnect between art and science was a disconnect over the roles played by the experts and the audiences. Where Maren, the dancer and choreographer of *Dance of Scales* sought to express something to audiences, Itai, the physicist involved in both projects, sought to explain something to them. I

suggest that explanation is a type of expression in which the creators of a text attempt to place specific constraints on how audiences interpret the texts. The theme of expression continues in Chapter 5, where I examine the development of *Emergence* to find that explanation was but one way of describing the kinds of constraints presenters were placing on their texts. Finally, in Chapter 6 I turn my attention toward interpretation and understanding, which are, in many ways, analogs to expression and explanation, but possess their own unique qualities.

In Chapter 7 I return to the discussion of public engagement and suggest that insights developed in these case studies, specifically, insights related to the relationship between expression, explanation, interpretation, and understanding, should be used to broaden the way we think about science communication. I call for the development of a new model for science communication that focuses on relationships between and among presenters, audiences, and texts, and uses explanation and interpretation as a basis for communication.

## CHAPTER 2: LITERATURE REVIEW

The intersection of art and science and the intersection of expert and audience can be thought of as continuums that exist on two axes. The first deals with the relationships of art and science: where do art and science meet? Can artists and scientists collaborate? What do they offer one another? What difficulties do artists and scientists encounter when working together? What value is in such collaborations? Questions on the second axis look within the social worlds of art and science; on the interactions between different groups of people in these worlds, specifically the relationship between experts and publics. How do experts envision their relationship with publics and vice versa? How do their preconceived ideas about this relationship manifest themselves in the way practitioners create the texts<sup>2</sup> with which audiences interact or to which they respond? And finally, the intersection of the two axes raises questions about whether the relationship between experts and publics is vastly different in the arts and science, how it differs, and what the intersection of art and science might teach us about that relationship.

This chapter is divided into three sections. The first will focus first on the relationship between art and science, drawing out the history of the two cultures as well as contemporary accounts of this relationship, the boundary work that goes in to maintaining the relationship, and the ways people traverse these boundaries to collaborate across disciplines. In the second part of this chapter I will turn to the relationship between publics and experts, and how that relationship is taken up in several disciplines relevant to the case studies examined in the dissertation. The final

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<sup>2</sup> By text, I mean the product created by these experts. This product may literally be a text, but it may be an image, a film, a performance, or even an exhibit. This loose use of the term text implies that there is something to be read in each of these kinds of texts, and for my purposes, they can be examined in terms of the creators and of the audiences who read them.

section of this chapter will draw together these two relationships and outline the research questions asked in this dissertation.

## **Art and Science**

### **The Two Cultures**

The history of the tension between art and science is long, but is perhaps best illustrated by the Snow/Leavis debates in the middle of the twentieth century. Though Snow's version of the two cultures and Leavis' response were not the beginning of the debate, they were certainly one of the most prominent episodes, and they remain the most often invoked. While Snow's ideas about the two cultures continue to capture peoples' imaginations, his technocratic view of scientific progress has been discredited by many scholars. C.P Snow's 1959 lecture on two cultures (C. P. Snow & Collini, 1998), or some variation thereof, is often the first thing that jumps to mind when art and science are mentioned in the same sentence. Snow's discussion of the two cultures rekindled a rancorous debate that, in some ways, continues today. Like Snow, many of the scholars and popular culture figures who proclaim the need for a merging of two cultures embrace technocratic ideals about the ways science can save humanity and the second culture. Other discussions move away from suggestions that the two cultures are separate and in need of reconciliation to focus instead on how one culture can be co-opted by the other. Various forms of boundary work (Gieryn, 1983; 1999) are at the heart of each of these conversations, and the questions around who is drawing these boundaries and why are often just as interesting as the ways the boundaries get drawn. In this section, I will discuss the original two cultures debate briefly, and touch upon the continuing dialogues (and in some cases monologues) concerning the

two cultures and the integration or segregation of art and science. Next I will examine the concept of boundary work and the tools used to establish boundaries and to legitimate social worlds (legitimation is a large part of boundary work, after all), and finally, I will discuss possible questions surrounding art/science integration and art/science social worlds.

The two cultures debate is the best place to begin because it is the most prominent and likely the most widely reinterpreted and even misinterpreted piece of art/science history. The term “the two cultures” became famous when C.P. Snow’s Rede Lecture in 1959 (Snow & Collini, 1998) ignited a heated, to put it mildly, debate between him and F.R. Leavis. Their long, acrimonious dialogue has been a subject of fascination for over half a century, and has been written about in academic and popular literature alike. By the end of the 1970’s, over 800 books, articles, essays, and reviews about the two cultures had been written (Elkins, 2008). Though this debate about the value of art and science from the mid-twentieth century is perhaps the most talked about and the most famous, it is not the first. Rather, it is one in a series of such debates between poets and philosophers through history (Ortolano, 2009, p. 5). Sandbrook (2006) points toward the debate between Matthew Arnold and T. H. Huxley in the 1880s as the precursor to the Snow/Leavis debate. Van Dijck (2003) and Snow himself trace the art/science divide to the industrial and scientific revolution. Van Dijck also notes that in the 1830’s the conferral of educational degrees was split into the Master of Arts and the Master of Sciences. This split, he claims, led to a professional split between the two groups.

In his lecture, Snow lamented the “gulf of mutual incomprehension” between the arts and sciences (C. P. Snow & Collini, 1998, p. 4). This gulf was marked by outward hostility between

literary intellectuals on the one hand and physical scientists on the other. Snow claimed that because he had had success in both of these cultures, he could walk between these two. He spoke about the value of both cultures, and his aim to bridge them, but it is evident from the lecture that he felt that science looked to the future, while the arts and humanities dwelled too much on the present and past. The remedy, he thought, was for the arts and humanities to turn their attention toward science. Snow's most adamant critic, F.R. Leavis, delivered his own speech in response to the two cultures lecture three years later. In his lecture, *Two Cultures? The Significance of C.P. Snow*, Leavis attacked the author rather than the lecture. As a literary scholar, Leavis found Snow's ideas and, more importantly (to Leavis' mind), his writing "beneath contempt" (Levin, 1965). Leavis claimed the humanities, specifically, literature, were morally and otherwise the superior culture (Cohen, 2001). A bitter fight ensued that drew its ammunition from far deeper arguments than the two cultures themselves (Ortolano, 2009), but the two cultures trope is what has been relived, revived, and rehashed since the early 1960s, even if the two cultures themselves have not remained static.

The two cultures have been reimagined in many different ways in many different literatures, constituting a mapping and remapping to suit particular arguments in particular fields. Such remapping may indicate that the kind of conflict Snow describes is somewhat universal, and thus seems applicable in many situations. But it may also be an indication that the idea of the two cultures is overly broad. The two cultures are commonly identified as science and art, or as science and the humanities (Burnett, 1999; Kimball, 1994; Kovác, 2002; van Dijck, 2003 to name just a few). But different incarnations have stretched the two culture construct as far as to characterize the two cultures as science and security (Kennedy, 2003). Today, fields as far

ranging as medicine and computing invoke the two cultures to describe chasms between different ways of approaching knowledge. As Burnett (1999) writes:

...In an essay in the New York Times on the New Luddites, Pynchon invoked the specter of what he called the “Snovian Disjunction.” It is a disjunction regularly lamented in scholarly symposia, cited by academic administrators, and invoked to help account for everything from the “science wars” to the history of environmental policy.” (P. 195)

The “science wars” Burnett mentions comprise perhaps the best example of this remapping of the two cultures. This particular map was drawn between “natural scientists and those nonscientists who take a professional interest not so much in the findings of scientific knowledge, but in the workings and nature of science” (Labinger & Collins, 2001, p. 3). In other words, this divide was between scientists and those in the field of science studies, which comprises the philosophy, history, and sociology of science. The science wars, at their essence, were between the realists on one side and the relativists (or postmodernists) on the other.<sup>3</sup> Cohen (2001) notes that there are differences between the science wars and the two cultures debates, and asserts that with its reconceptualization of science (as a social practice with local knowledge), science studies has effectively eliminated the two cultures.

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<sup>3</sup> Though the science wars had been brewing for some time, they began with Gross & Levitt’s *Higher Superstition* (1994), but grew more visible in 1996 with what is now referred to as the Sokal affair. Alan Sokal, a physicist at NYU wrote and submitted an article to the cultural studies journal *Social Text* (Sokal, 1996a). After the article was reviewed and published in the journal, Sokal revealed his article as a parody, and wrote extensively about his “experiment” in *Lingua Franca* (Sokal, 1996b). Sokal’s aim was to see if *Social Text* would publish “an article liberally salted with nonsense if (a) it sounded good and (b) it flattered the editors’ ideological preconceptions” (Sokal, 1996b, p. 62). The fallout from these two articles was considerable, with academics choosing sides and what could have been a fruitful discussion about the relationship between science and science studies devolving into mudslinging. In 2001, Harry Collins, a science studies scholar, and Jay Labinger, a chemist compiled an edited volume, *The One Culture?* to help advance a more respectful, serious dialogue between the two cultures (Labinger & Collins, 2001). Though much of the fire of the original science wars has subsided, in 2008, Sokal published a book in what amounts to an attempt to rekindle the heated debate (Sokal, 2008). A brief new battle emerged in the pages of *Reviews in Anthropology* in 2010 and 2011 (Schultz, 2010; 2011; Smith, 2011; Sokal, 2011).



The two cultures make sense as a rhetorical strategy and from the point of view of recognizable practices. As a theoretical and epistemological distinction, however, the divide cannot hold up under a revised (science studies) notion of science.  
(Cohen, 2001, p. 11)

It is interesting to note that throughout all of the mappings and remappings of this debate, the one culture, science, has remained roughly the same: the physical, natural, and experimental sciences; however, the other culture has been adapted as different fields have (willingly or unwillingly) joined the fray: humanists, artists, social scientists, those who study science, and even, as was suggested at a symposium on the two cultures in New York in 2009, the public. Why the shifting second culture? Snow wrote and spoke about the two cultures in terms of their focus on the future (science) and on the present and past (the humanities). Science and technology, according to Snow, would help solve the world's problems. It was up to art and literature, therefore, to turn their attention to the sciences and embrace them, so that they could also focus on the future rather than the past. The narrative that science or technology will save us from ourselves, if only we embrace it and incorporate it into [insert thing that needs rescuing] is echoed in E. O. Wilson's *Consilience* (1998). Wilson's hope is that as fields like sociology will be subsumed by biology, where scientific explanations will replace what might be considered interpretive insights. The result will be a merging of these fields, with the rules and methods of the natural sciences as the model for what's to come.

There are many who, like Wilson, seek a third culture that merges the two. While the term third culture has several other meanings related to trans- and cross-cultural relationships, the meaning here is derived from the two cultures debate. Some consider the social sciences (Fallers, 1961;

Kagan, 2009; Skorton, 2010) an extant third culture overlooked by Snow. In 1961, before Leavis' response, and before Snow's additional comments on the two cultures debate were published, Fallers responded by suggesting that Snow had completely missed the existing third culture of the social sciences. He went further to criticize social scientists for not doing enough to bring attention to the importance of their work, and finally, to sharply criticize Snow for suggesting that science and technology, rather than an understanding of humans and society, would cure all of the world's ills.

Only natural science and engineering, [Snow] says, understand progress of the sort that the new states need. He would therefore have us compete with the Soviets by becoming technocratic barbarians, deliberately ignoring the social and cultural prerequisites and consequences of technological modernization. (Fallers, 1961, p. 310)

When Snow himself revisited the two cultures and discussed the third culture, he envisioned minds that were familiar with both the arts and sciences, but embraced the forward thinking nature of science. As Snow maintained throughout his discussion of the two cultures, it was important for artists and humanists to embrace the future and think about how the sciences can, in effect, save the world:

With good fortune, however, we can educate a large proportion of our better minds so that they are not ignorant of imaginative experience, both in the arts and in science, nor ignorant either of the endowments of applied science, of the remediable suffering of most of their fellow humans, and of the responsibilities which, once they are seen cannot be denied. (C. P. Snow & Collini, 1998, p. 100)

Brockman (1995) continues this vein of thinking that the sciences will solve our societal problems. He advocates a third culture not in which literary intellectuals communicate with scientists, but one in which scientists communicate “directly with the with the general public” (p. 18). The third culture he describes includes scientists who think and write about the implications of their work for the general public. These scientists/intellectuals include Stephen Jay Gould, Richard Dawkins, and Lynn Margulis. It seems as though Faller’s initial critique of Snow might also apply to Brockman. Somewhat like Brockman and Snow himself, Kevin Kelly (Kelly, 1998) writes about the third culture as a “nerd culture,” driven by innovation and invention rather than theory:

This new third culture is an offspring of science. It’s a pop culture based in technology, for technology. Call it nerd culture. For the last two decades, as technology supersaturated our cultural environment, the gravity of technology simply became too hard to ignore. For this current generation of Nintendo kids, their technology is their culture. When they reached the point (as every generation of youth does) of creating the current fads, the next funny thing happened: Nerds became cool. (p. 992)

Kelly’s concept of technology as the third culture does little to bridge the classical arts and sciences, but, in his estimation, creates a connection between popular culture and classical science because “classical science will have to thrive in order for the third culture to thrive, since technology is so derivative of the scientific process” (Kelly, 1998).

These concepts of the third culture take on a pointedly technocratic idealism about the role science plays in culture and in society. Just as Snow’s assessment of the two cultures did not

value the arts as highly as the sciences, these ideas of a third culture as scientific or technological do not leave much room for the value of the arts. Rather, they highlight the ways art, technology, or popular culture can help to elevate the sciences, especially in terms of spreading the word about the sciences so they can continue to better humanity and solve the pressing problems of our time. At the same time, their ideas are rooted in the belief that science can help produce better culture.

Moving away from the two cultures debate, some scholars focus on existing relationships between art and science, as well as potential future relationships. These relationships are not built explicitly on the two cultures framework, and may, therefore, escape the technocratic underpinnings of Snow's original argument. But observations about the inherent lopsidedness of existing relationships between art and science cannot be avoided; in most conceptualizations of art/science integration, one of these fields becomes subservient to the other. Ede (2002) breaks art/science relationships into three categories: art that uses science, art that assists science, and, finally, metaphors used in art and science. Specifically, she identifies scientific metaphors that, while they may rest within some kind of scientific knowledge, do not produce new knowledge about science. Heisenberg's uncertainty principle is one such metaphor; it is often used to speak about one's inability to know oneself, or about the way that observation often changes the nature of that which is observed.

Similarly, Elkins (2008) lists four ways these disciplines can be used to illuminate or think about one another in art history. First, science can help explain art, as, Elkins suggests, is the case when the use of color in Seurat's *La Grande Jatte* can be explained, in part, by Chevreul's color theory

(Elkins, 2008, p. 9). Second, and possibly more commonly, art can be used to explain science. Daston and Galison's discussions of objectivity in anatomical drawings provide an excellent treatment of one such case (Daston & Galison, 1992; 2007). Third, both art and science can be explained by some other field, for example, philosophy. The point here is that philosophy itself is the explanatory lens for these parts of culture (or cultures) rather than the sciences or arts, and so, the analysis does not speak from art and science. Fourth, Elkins says, are situations in which "various disciplines are put in ambiguous conjunction" (p. 11). Elkins uses Jonathan Crary's (1999) work as an example. He notes that Crary writes about different aspects of a specific culture (Western Europe in the nineteenth century) as being connected because they come from the same culture without the need for finding specific links or defining clear relationships.

When I began my work as a scholar, I shared the restlessness with which these proponents of art/science collaborations perceive as the existing ways art/science collaborate, and when I began this project, I longed for what might be seen as a "real collaboration" between the two, in which the product is neither or both art and science. I also shared the hope of a way to write about art and science that speaks to both artists and scientists. Elkins believes discussions of art and science often fail for several reasons (2008), including the failure of metaphors to relate directly to the disciplines engaged; the way art and science are read is cognitively quite different; and perhaps most importantly, because in most cases one discipline is being used to illuminate another, and the relationship is not made clear.

## **Crossing Boundaries**

These discourses around the two cultures, especially those that predict that the humanities will be subsumed somehow by the sciences, are fascinating examples of boundary work (Gieryn, 1983; 1995; 1999). Gieryn discusses boundary work in terms of how scientists separate their own work from nonscience; however, the concept is applicable to other domains in which specialized knowledge is demarcated from other kinds of knowledge.

[Scientists'] attribution of selected characteristics to the institution of science (i.e., to its practitioners, methods, stock of knowledge, values and work organization) for purposes of constructing a social boundary that distinguishes some intellectual activities as "non-science." (p. 782)

Gieryn describes boundary work in the sciences as a kind of rhetorical cartography wherein scientists work to establish and maintain epistemic authority. The cartographic metaphor is quite useful here: "Maps do to nongeographical referents what they do to the earth. Boundaries differentiate this thing from that; borders create spaces with occupants homogeneous and generalized in some respect (though they vary in many other ways)" (Gieryn, 1999, p. 7). Maps are also a useful mental image because it is easy to imagine how they get drawn and redrawn as territory is lost or gained, as treaties are declared, or as powers merge.

Maps must not only simplify, distill, and reduce their referents, but then reconfigure, distort, and embellish them. It is not immediately obvious where to look for science-the-real-thing in order to check the accuracy of a certain cultural map—or at what, at whom, and when. Science—as practiced, as written up in technical papers, as regulated by the norms of research conduct—has a

robustness, a plenitude, a scale that defies complete mapping. Selections from this real science must be made by cultural cartographers, and they are—strategically. (Gieryn, 1999, p. 19)

Boundary work consists of several specific kinds of marking up of cartographies of credibility.

Gieryn characterizes the three activities as expulsion, expansion, and protection of autonomy<sup>4</sup> (1999). Expulsion describes instances in which competing authorities seek to legitimate their claims as scientific. Neither side challenges the epistemic authority of science, but they vie for space within that authority, and seek to oust the other from that space. Expansion describes instances in which authorities vie for “jurisdictional control over a contested ontological domain” (p. 16). These cases do not assume science has epistemic authority, but instead, seek to either extend science’s authority to new realms or to challenge the privilege given science over truth claims. Finally, protection of autonomy looks a bit different from the other two forms of boundary work. Gieryn describes several scenarios in which outside powers seek to exploit the epistemic authority of science, often compromising the resources or power held by scientists. Scientists may need to work to protect their autonomy over what kind of research they do in light of corporate or political interests; they may find the need to reestablish their authority in the wake of an attack by the mass media; or they may wish to distance their work from its consequences.

These descriptions of boundary work make it clear that it is not solely the scientists, up in their ivory tower, who engage in the creation of these rhetorical cartographies just as it is not only artists who decide what is and what is not art. According to Gieryn, “Ordinary folks seek out

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<sup>4</sup> In his first article on boundary work (1983), Gieryn lists the three activities as expansion of authority into domains already claimed by other areas, monopolization of authority and resources, and protection of autonomy.

cultural maps to locate credibility; fact makers produce maps to place their claims in a territory of legitimacy” (1999, p. 14). Beyond scientists and “ordinary folks,” politicians, corporate interests, media, and other groups play roles in shaping and reifying the boundaries that run through the sciences to demarcate one kind of science from another, or science from non-science. Each in each case of boundary work, the clear demarcation of what *is not* science helps point the way toward what *is* science, not only for scientists, but for the rest of us as well.

Though Gieryn does not provide a detailed account of boundary work in the arts, presumably one could be written. Artists and art critics cannot make the same kind of claims on epistemic authority as scientists, but they can make authoritative claims about the arts, and boundary work between professional and amateur artists, critics and audiences, is commonplace. In both the arts and sciences, boundary work does not just occur on grand scales; it is not simply whether something falls into the categories of art or science, or not. Boundary work happens within disciplines and sub-disciplines, and separates one kind of science from another. Rather than repeat the examinations of art and science discussed in the first part of this chapter, I intend to focus on the social worlds in which art and science are created; to examine the ways artists, scientists, and others who participate in these endeavors characterize their work and the differences between their work and the work of others.

## **Social Worlds**

Gieryn’s descriptions of boundary work are focused on specific examples within specific fields. This, I believe, is why they tell us much more about interdisciplinary relationships than do the two cultures debates, which seem to be focused on the grand concept of “cultures” and often



remain vague and opaque. The concept of culture is large and encompasses too much to adequately discuss specific terms in which art and science can collaborate. Similarly, general discussions of art and science try to encompass too many disciplines that operate differently. For example, paleontology is an entirely different kind of endeavor from particle physics, just as painting is vastly different from film or theatre, though the subfields are related by shared epistemologies, values, and goals. The boundary work might be vastly different in each field. By shifting focus from the grand concept of cultures to tangible areas of practice, individual cases of boundary work and boundary crossing in the arts and sciences can help illuminate the relationship between art and science. Using social worlds as a lens affords me the opportunity to examine the kind of boundary work that occurs in specific situations in which art, or science, or both, are processes handled by interconnected groups of people doing work on specific scientific or artistic problems and projects. I am also able to examine the differences between artists' and scientists' conceptions of their relationship to knowledge and the public, as well as the public's perceptions of their relationship with experts and knowledge. This, to me, opens a far more productive way of conceptualizing the intersection of art and science, while at the same time, allowing room for the discussion of the ways art/science collaborations complicate the relationship between experts and publics.

Social worlds are defined as “groups with shared commitments to certain activities sharing resources of many kinds to achieve their goals” (Becker, 1974; 2008; quoted in Clarke, 1997; Strauss, 1978). The concept of social worlds originated with the symbolic interactionists of the Chicago school. In the 1950's Shibutani first wrote about what has come to be known as social

worlds as loose organizations without a need for formal boundaries or face-to-face communication (Shibutani, 1955; 1961; Unruh, 1980).

Strauss and Becker further developed the concept of social worlds in the 1970's and 1980's, building on the idea of loose, informal networks of people fulfilling different roles, and added the idea of communal commitment to a set of ideas and ideologies. Many sociologists in both the arts and sciences have adopted the social worlds approach. In 1995, Gieryn described a social world as "a group with shared commitments to the pursuit of a common task, who develop ideologies to define their work and who accumulate diverse resources needed to get the job done" (Gieryn, 1995, p. 412), adding the development of ideologies as well as resource accumulation. These additions are astute descriptions of concepts about which scholars writing about social worlds were already thinking. Thus, a list of key aspects of social worlds would include 1) distributed work, 2) shared commitments, 3) shared and developing ideologies, 4) loose organizational structures, 5) mediated communication, and 6) resource accumulation.

*Distributed work.* Not everyone in a social world performs the same task, differentiating social worlds from, for example, academic fields of study. Though there are similarities between social worlds and fields of study, and certainly a social world could arise within a field of study, social worlds include all of the actors that work to make the social world function. In an art world, this might include painters, their assistants, gallery owners, patrons, manufacturers of materials like canvas and paints, and so on.

*Shared commitments.* Actors of social worlds may not perform the same tasks, but they have the same commitments to a product or social movement. For example, all of the people involved in

a theatrical production, be they audience members, actors, stagehands, or users, are committed to taking part in a full production.

*Shared ideologies.* Again, though actors in social worlds may not share exactly the same belief system, they will have shared ideologies. People organized around a social movement will believe in that movement, and that belief will help them to forge ahead. Their shared ideologies lie beneath and support the shared commitments they have to the social world.

*Loose organization.* Social worlds are not, by definition, formally organized. Though a formal organization, like a political campaign PAC, may play a prominent role in a social world, the world will include many people from outside the organization.

*Mediated communication.* Mediated communication was important in early social worlds work, because of its roots in the Chicago school, which was known for its role in the sociology of mediated communication. Mediated communication is now so commonplace in any group or organization, this aspect may seem a given; however, its significance here is tightly tied to its facilitation of loosely structured communities, working together. So, while this characteristic may not be unique to social worlds, it is certainly important to them.

*Resource building.* Social worlds accumulate resources, including money, space, and human resources, to produce their work. Put simply, the actors in a social world have a shared economic interest as well as an ideological one. In a science world, this might appear quite straightforward: grants and university funding might keep a lab operational; undergraduates and graduate students might work in the lab, and would thus be a part of the social world; and the lab might operate

within a the departmental social world in which high cost equipment, like FMRI machines or electron microscopes are shared. In an art world, this might be much more complex: resources may come from patrons, audience members, students paying for classes, grants, and the sale of tickets or artworks.

Taken together, these characteristics do several things. First, they privilege process over structure, so that, as analysts, we can bound social worlds by the work they do rather than the structures within which they exist. Next, they do not prescribe a specific scale or structure, leaving the analyst to describe the structure they find in a field study. They also emphasize the relationships between actors, especially actors playing different roles, and provide a lens through which to examine the communication between actors. Finally, the centrality of process (rather than structure) provides a framework in which social worlds have the ability to form and reform, to shift, and to grow and change over time. Social worlds can be studied at any scale, making the approach even more flexible (Clarke, 1990; 1997; Gerson, 1983; Strauss, 1978).

Because social worlds are in constant evolution, the stable characteristics described above must be augmented with descriptions of the dynamic processes that occur with the formation and re-formation (and dissolution) of social worlds. Strauss identified three types of processes that occur as social worlds form and reform: segmentation, intersection, and legitimation (Gerson, 1983; Strauss, 1982; 1984).

Segmentation occurs when subworlds form and split from their initial social worlds. Gerson (1983) gives the example of zoology first bifurcating to form vertebrate and invertebrate zoology, and then further spitting into subworlds of entomology, ornithology, etc. In the arts, this

might look a bit like the world of dance spawning modern dance, then schools of modern dance, like Graham or Humphrey. Segmentation continues infinitely, leading to greater and greater specialization and, “the depth of specialization [is] limited by the scope and complexity of the phenomena, on the one hand, and the available scientific labor supply, on the other” (Gerson, 1983 p. 360).

Intersection happens “when a single activity or cluster of closely related activities simultaneously comes to be part of two or more lines of work” (Gerson, 1983, p. 363). For example, the rise of disciplines like biochemistry and physical chemistry arose from the intersection of social worlds. Gerson describes the intersection of social worlds as “a system of negotiating contexts, in which resources flow between social worlds” (p. 363). Intersection that results in new social worlds is usually long-term, and involves much negotiation and re-negotiation. The resulting world, however, is mutually beneficial for the intersecting worlds because resources, knowledge, and/or prestige are increased for members from both of the intersecting worlds.

Finally, the members of social worlds are constantly engaged in legitimation, which occurs in both segmentation and integration processes. Strauss (1982) describes several types of legitimation: Discovering and claiming truth; theorizing; standard setting, embodying, evaluating; distancing; and boundary setting and challenging.

Discovering and claiming truth is an integral part of any social world or subworld, and is tied directly to the idea that members of a social world possess shared commitments and ideologies. “Truth” in this case may be about the particular domain of the social world. For example,

articulating the truth, or human value, their collective work strives toward is a part of the work they do together as a social world.

A belief and then the claim that a particular path will lead to something of human value, and sometimes to significantly great value and even essential truth...seems integral to the formation of any [sub social world]. (Strauss 1982, p. 175)

As a subworld forms, it must “forge its own ideological weapons” (p. 177). This forging, or theorizing, works with the claiming of truth to form the ideological basis for the social world.

As social worlds develop, practices become standardized, and criteria for evaluation emerge. Setting standards and evaluating practices in social worlds, then, are ways to build the world and to set the bar for those who work within that world. In science worlds, there may be formal standards that must be passed. Specific statistical criteria are often adhered to in the quantitative social sciences. In other worlds, the standards may emerge a bit differently. Strauss (1982) recounts the way astronauts were once scorned by ‘real pilots’ as little more than monkeys in a flying box, but how, over time, they worked to establish themselves as indispensable and built a reputation for themselves as the most elite pilots in the U.S. Air Force.

Often, when the difference between a new subworld and an existing social world are not clear, the new subworld must convince the world at large of its own “worldness.” In such instances, distancing is employed to move the subworld away from its parent world or worlds. This distancing, an example of boundary work in the development of social worlds, also informs our understanding of boundary work as flexible and highly dependent on context. In two of his articles (1982; 1984), Strauss uses the example of ethnomethodology as an illustration of

distancing: “We are ethnomethodologists and not symbolic interactionists or even phenomenologists” (1982, p. 176). Distancing is part of the legitimation process.

Legitimation plays a central role in the growth and maintenance of a social world. Thus far, I have discussed internal forms of legitimation, but when legitimacy is bestowed externally, it can be a boon to the establishment or stabilization of a social world. For example, internal legitimation may occur when a theatre community works to establish themselves as a legitimate social world within the larger New York theatre community by differentiating what they do (a consortium of avant-garde theatre companies, for example) from the rest of the theatre world. However, external legitimation may come when a newspaper, like the *New York Times*, writes an article about the subworld.

I would be remiss not to point out the weaknesses of an analysis based on social worlds. Because the concept is abstract and flexible, and because the relationships and other characteristics that define social worlds are always in flux, it is not easy to bound social worlds, or to delineate what is and is not a social world. While flexibility is one of the great strengths of social worlds, and one of the ways they are differentiated from disciplines or fields, it is also a weakness. The lack of formal structure makes it quite easy to claim that anything can be a social world. Because of this weakness, I believe there is an additional criterion for what constitutes a social world: there must be an overall sense of a social world; a way in which these characteristics and actors fit together as a whole, as well as a way in which the members of the world, themselves, recognize their own “worldness.” It is this worldness” that makes social worlds a valuable lens for these cases. The audiences are bound into the worlds, and social

worlds as a way of analyzing the activities builds in ways of considering audiences as part of the work being done rather than spectators for that work.

## **Boundary Objects**

Delving more deeply into the inner workings of social worlds, Star and her colleagues have introduced the concept of boundary objects as ways for members of different social worlds<sup>5</sup> to engage with one another (Bowker & Star, 1999; Star, 2010; Star & Griesemer, 1989). Boundary objects, according to Star & Griesemer (1989), are “those scientific objects which both inhabit several intersecting social worlds...and satisfy the informational requirements of each of them” (p. 393). Star and Griesemer use an example of a map of California as a boundary object that is used differently by different members of the community. The scientists used the map, along with scientific and mathematical markings, to share highly technical knowledge, while the collectors and conservationists would use and mark the map as the average person would use a road map: to denote places to collect specimens, camp, etc. Boundary objects are useful insofar as they facilitate collaboration between actors from different social worlds<sup>6</sup> while leaving room for individual interpretation of meanings and uses. Boundary objects possess three characteristics: 1) interpretive flexibility (this is the primary characteristic for which they are

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<sup>5</sup> Between the first article on boundary objects in 1989 and the latest in 2010, Star shifts from writing about social worlds to writing about communities of practice (Lave & Wenger, 1991). In their book, Bowker & Star (1999) use the two interchangeably, and note that they are replacing the concept of social worlds with that of communities of practice. While the use of either term may not change their concept of boundary objects, the former, social worlds theory, is a much more apt construct for discussing the intersection of art and science in my cases because the “worldness” of a social world carries with it the structures, such as funding streams and institutions, that support the social worlds, while communities of practice may form or dissipate on a more ad hoc basis.

<sup>6</sup> Star & Griesemer define boundary objects as inhabiting several social worlds, but it seems to me that from a symbolic interactionist perspective, the volunteers and the scientists might inhabit the same social world. Perhaps then, boundary objects would still be useful and necessary in translation across different categories and actors within the same social world, but the objects would still be boundary objects because they crossed between different social categories within the worlds; they helped people who have different occupations within a social world to interact with one another.



known now), 2) they reside between social worlds, or interpretive communities, and 3), they are conceptualized both vaguely for collaborative work and specifically for work within a particular structure. These three characteristics, taken together, make for objects that allow interdisciplinary groups to collaborate without the need for consensus (Star, 2010). Such objects, then, would undoubtedly be employed by a group of artists and scientists working together.

The concept of boundary objects has been built upon extensively in a number of fields, especially in its field of origin, science studies, and in the design world, particularly in human computer interaction and computer supported cooperative work. In these fields, many scholars built on the foundation of boundary objects. For example, Henderson (Henderson, 1999; Lee, 2005) describes “conscription devices.” Boujut & Blanco (2003) describe “intermediary objects.” Lee (2005) aims to describe artifacts that “can serve to establish and destabilize protocols themselves and that artifacts can be used to push boundaries rather than merely sailing across them” (p. 388). She proposes a new concept that succeeds where boundary objects do not. Her concept, boundary negotiating artifacts, is meant to be used in situations too unstable or chaotic for collaboration without consensus. Thus boundary negotiating objects are used to “iteratively coordinate perspectives and to bring disparate communities of practice into alignment, often temporarily, to solve specific design problems that are part of a larger design project” (p. 394).<sup>7</sup> In science studies, Fujimura writes about standardized packages (1992), which are particularly useful in the sciences because they are meant to describe “both collective work across divergent social worlds and fact stabilization” (p. 169, *italics in original*).

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<sup>7</sup> Lee focuses specifically on design here, but it is not difficult to imagine the exact same sentence sans the focus on design, “iteratively coordinate perspectives and bring disparate communities of practice into alignment, often temporarily, to solve specific problems that are part of a larger project.”

Standardized packages are “gray boxes” that contain several boundary objects along with a set of standardized methods.

Guston (2001) introduces the idea of “boundary organizations” as a way to facilitate the use of boundary objects and standardized packages. While standardized packages were developed by more fully exploring the boundary objects as portable artifacts or ideas, boundary organizations are a way of thinking about the structures within which people work with boundary objects and standardized packages. Boundary organizations serve three functions. First, they facilitate the creation and use of boundary objects and standardized packages, second, they bring together professionals from both sides of a boundary by employing professionals who mediate between different social actors, and finally, “they exist at the frontier of the two relatively different [social worlds] but they have distinct lines of accountability to each” (p. 401). Guston’s examples of boundary organizations include the Congressional Office of Technology Assessment (OTA) and the Health Effects Institute (HEI). These are organizations, so they are formally structured, unlike social worlds. Guston sees these organizations as organizations that “perform tasks that are useful to both sides, and involve people from both communities in their work, but play a distinctive role that would be difficult or impossible for organisations in either community to play” (quoted in Guston, 2001; Scott, 2000, p. 15).

Is there something about the structured nature of an organization that allows boundary organizations to function in the ways Guston describes, or could there be a boundary world, a social world that is formed in between? This idea of a boundary world is central to the question of how art and science intersect. Would an art/science boundary world be useful to both? Would

the product be both or neither art and science? Is such a world created when art/science come together? One of the recurring themes of the cases presented here involves the work done at these boundaries, and the subsequent boundary work, the boundary objects created or used, and the question of what place the work occupies in larger fields. How is it relevant to science worlds or art worlds?

Perhaps the largest question about these potential boundary worlds remains the question of who the audiences are. What role do audiences, or publics, play in any given art world or science world? What do these roles have in common across different social worlds? It might seem obvious to state that the role of the audience in art worlds has been considered much more thoroughly than in science worlds, where it has barely been addressed, except to note where some social worlds may be more publicly visible than others (Clarke, 1997; Strauss, 1978). In most art worlds, the role of the audience (or intended audience) is articulated and included in most discussions. Becker notes the way shared knowledge of conventions allows artist to elicit the desired emotional response from audiences. Van Maanen (2009) also notes the other actors in art worlds that mediate the relationship between the artist and the audience. “In ‘a society of any complexity’ the roles of artists and audiences are often made functional by means of a third type of role, filled by mediating personnel, such as producers, theatre managers, art dealers and critics” (p. 26). But for deeper considerations of the relationships between artists or scientists and experts we must move beyond current discussions of art worlds.

## Publics and Experts

### Public Engagement

The term engagement has come to mean a number of things in science communication and informal science education. These two adjacent fields have embraced the concept of engagement as a way of improving the way they conceptualize the relationships between experts and publics, but it has come to be highly problematic in both. In science communication, the call for engagement began as a call for an open dialogue between scientists, policy makers, and publics, and for scientists and policy makers to learn from publics, just as publics learn from scientists. At the time, this was a way of correcting course for some deeply flawed ideas about how and why scientist and other communicators should approach public communication of scientific knowledge. These interconnected, but distinct conceptions of engagement might be classified as *engagement as exchange* and *engagement as interaction*. The first, engagement as exchange has its roots in political theory, namely, deliberative democracy (CAISE Informal Science Evidence Wiki, n.d.). The second use of engagement, found in Informal Science Learning circles, *engagement as interaction*, reflects the ways informal (and perhaps formal as well) education programs attempt to design their projects to include the learner as an active participant. Participation may be part of both of these forms of engagement, but that participation can come to mean very different things.

#### *Engagement as Exchange*

Public engagement in or with science (PES), the current dominant model of science communication, is not without its share of criticism. While many of the critiques are justified and

point to large issues inherent in the model and in the way it is taken up and used in practice, the value of PES becomes apparent when seen in light of the practices it was developed to counter. The movement toward engagement brought to light the highly problematic ways in which the relationships between science and publics were conceptualized and the effectual practices that stemmed from those beliefs.

In 1985, when the Royal Society's report on Public Understanding of Science (1985, known as the Bodmer report) was written (Bodmer, 1985), the dominant view was of the public communication of science as a transmission of scientific knowledge from the heights of the ivory tower, where scientists were busy creating knowledge, down to the public, who needed to be informed of scientific progress. This deficit model, so named for the assumption of the public's deficit in knowledge, also goes by the name of science literacy. Science literacy, like those basic skills of reading and writing in grade school, was seen as something all adults should possess; however, surveys in the US and Britain, then globally, showed a serious lack of what was considered basic science knowledge (Bauer et al., 2007; Durant, Evans, & Thomas, 1989). This idea that knowledge needs only to be passed down from the knowledge producers (scientists) to the empty receptacles that make up the "general public" persisted, and was driven by the dismal numbers that emerged when the public was actually tested. The test harkens back to Snow's test for the literary elite in which he took it upon himself to ask them at parties if they could define the first law of thermodynamics. He may have proved the point that they could not correctly answer his question, but that was not important to them, nor did it tell him more broadly what they thought or understood about science. As scholars began to examine this problem of science

literacy (or lack thereof), they further developed their criteria of what it meant to be literate about science.

The public understanding of science (PUS) model emerged through this discussion. It is important to note that these different models are not discrete entities, but rather, iterations of a process of dealing with what was (and often still is) seen as a fundamental problem of disconnect between scientists and publics. PUS continued to focus on knowledge and understanding (read appreciating) the pursuit of science. The PUS model took on a formal meaning after the publication of the Bodmer Report, which called directly on scientists to communicate their work to a wider audience. This report helped legitimize science popularization (S. Miller, 2001), and was a positive step toward communicating science not as a series of facts, but rather, as a dynamic process (House of Lords, 2000). The Bodmer Report also began a movement that included both action and reflection on the nature of PUS. Scholarly research begun under this movement helped move the field of science communication beyond the deficit model. Deficit thinking as well as PUS focused primarily on disseminating knowledge from scientists to the public, and did not consider whether the public had something to say.

However, the underlying aim of fostering appreciation for science did not stand up to complex scientific policy decisions, like the use and labeling of genetically modified foods. There was a real need for open dialogue to shape science policy rather than cheerleading after decisions were made (Bauer et al., 2007). PES, also called the science and society model, is an endeavor to break from these top-down approaches to science to make room for open discourse about scientific knowledge and its ramifications (Leshner, 2003). This model of engagement was

touted as two-way communication in which the public is able to communicate concerns and opinions “upstream” to policy makers and scientists. Ushered in at the turn of the 21st Century by a House of Lords report in the U.K. (House of Lords, 2000) and by the then CEO of the American Association for the Advancement of Science (AAAS), Alan Leshner in *Science Magazine* (Leshner, 2003), the engagement model was developed, in part, to cope with a perceived growing public mistrust of the scientific community. Miller cites this shift as one that would “[clear] the way for full, frank, and publicly inclusive dialogue, discussion, and debate about science and its implications for individuals and society” (S. Miller, 2001, p. 119).

Engagement activities include opinion surveys, citizen juries, consensus conferences, and similar events in which the public is invited to a forum where they are given opportunities to voice their concerns about the implementation of new science policy and new technologies (Joss, 1999). Other activities that foster interaction, or, what Hilgartner (1990) calls upstream/downstream communication, include science cafes, science festivals, and science shops (Rowe & Frewer, 2000; 2005).

Some scholars turned their focus to ways that public encounters have shaped knowledge production in the sciences. Lewenstein’s (1995) web, or sphere (Brossard & Lewenstein, 2010; Lewenstein, 2011), of science communication builds on this idea to show the ways publics, governments, media, and cultural institutions inform, and, in some cases, spark new scientific knowledge. For example, an exhibit on the rainforest developed for the National Museum of Natural History (NMNH) in Washington, DC led to many new scientific discoveries because scientists were sent to the field to collect samples and data to create the exhibit (Lewenstein & Allison-Bunnell, 2000; Phillips, Lewenstein, & Bonney, 2006). Similarly, Lewenstein (1995)

discusses the role the news media played in the cold fusion scandal in the late 1980s. These efforts draw attention to the ways publics inform science and make a strong case for thinking about science communication not as a one way activity in which knowledge is created and then passed downstream to publics, but as a vital part of the process of knowledge creation. Certainly, these studies illustrate a level of complexity inherent in science communication, and they point toward a more complex structure than much of the literature that focuses on up- and downstream communication suggests.

After almost fifteen years of working with the engagement paradigm, science communication scholars have uncovered the problems and pitfalls of this often too vague and occasionally idealistic idea of what the relationship between science and the public should be. First, critiques have been offered over the lack of clear criteria for evaluation of PES, and even a clear definition of engagement.

The evaluation of public engagement exercises is full of difficulties, ranging from the theoretical (what do we mean by effective public engagement?) and practical (how do we go about measuring effectiveness in the highly complex engagement environment?), to the political (how does one conduct evaluations in an environment full of competing parties with contrasting motives?). (Rowe, Horlick-Jones, Walls, & Pidgeon, 2005, p. 349)

Beyond the trouble with evaluation, PES has come under scrutiny for many reasons, and criticized for, among other things, paying only lip service to the idea of an open, equal exchange between publics and scientists (Joss, 1999; Wynne, 2006), of using events promoted as ways of encouraging upstream engagement only to push a specific agenda on the public (Bauer et al.,



2007), and of failing to clearly articulate science or conceptualize publics (Irwin, 2014; Jasanoff, 2014). Wynne. (2006, p. 213) cites the inability of the scientific community to learn from the public through an exchange of dialogue as a significant problem: “Institutional scientific learning about its own culture and its embodied assumptions about ‘the public’ has so far largely failed.” Part of the aim of learning from the public, in this case, was to better understand the perceived mistrust of the scientific community so that it might be addressed.<sup>8</sup> Despite all of its faults, the engagement movement is not seen by most of its critics as disingenuous. Even in his scathing critique of engagement, Wynne calls the engagement model “difficult to dismiss as anything but sincerely intended” (Wynne, 2006, p. 213).

Thus far, critique of public engagement seems to have reached a crescendo in a recent special issue of *Public Understanding of Science* on public engagement. The journal invited some of the major figures in the field to offer their thoughts on the state of PES, and, while they all found clear issues with PES that needed addressing, they also found great value in the steps taken by engaging with engagement.

There is much that is to be welcomed in the turn away from naïve deficit model thinking toward more dialogical approaches to the interface between science and the public. However, as the participatory movement attempts the awkward transition from high theory to complex and messy practice, a number of dilemmas are encountered which problematise the notion of public engagement as a potential solution to the ‘wicked’ problems of science governance. (Sturgis, 2014, p. 38)

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<sup>8</sup> At the other extreme, engagement as exchange has also been faulted (though not by many science communication scholars) for failing to impart basic scientific knowledge. How can publics debate science policy if they do not understand science fact? (Edwards, 2013; J. D. Miller, 2012)

Despite the pitfalls of engagement, I do not believe these scholars were suggesting it is time to move on. Rather, they seem to aim to breathe new life into the idea of engagement. I address this special issue separately in part because it comes at the tail end of the investigation of engagement I am conducting for this dissertation, but in part because it seems to be a reset button of sorts; a way for those of us in the field who have been working less than successfully within the engagement paradigm to collectively allow ourselves space for new ideas. Irwin suggests new contexts in which to explore engagement:

We need new stories to tell about engagement, stories which connect issues large and small and which confront us with both the challenges and the possibilities. We need to explore diverse (and especially non-Western) contexts and settings and be aware of the different meanings that can be attributed to PES. We should not consider practice and critical reflection as separate activities but take ‘reflective practice’ and ‘practical reflection’ equally seriously. We should recognise that ‘PES’ is a profoundly flawed and problematic construction which in many ways promises more than it can ever deliver, but understand that (at least for now and in some settings) it can be a valuable tool for the unpacking of larger questions. And we should hope that in another twenty years we will all be a lot wiser than we are today. (Irwin, 2014, p. 74)

The calls to action in these articles are many, and they are on point. Within this issue there are calls to reexamine our definitions of both public and science (Jasanoff, 2014; Wynne, 2014). Several scholars call for a further examination of the power dynamics at work in PES. Horst (2014) and Nowotny (2014) ask us to think about top down (institutional, whether governmental or informal) vs. bottom up (citizen led social media initiatives, geeks, makers etc.) engagement (Stilgoe, Lock, & Wilsdon, 2014). The general shift is toward approaching the problem from

where the publics stand (at least the already interested publics) rather than where the scientists and science communicators stand. Lastly, and in anticipation of the subsequent section of this review, Stilgoe et al. (2014) touch on the divide between engagement as exchange and engagement as interaction and ask us to seek the bridges between informal science communication endeavors and questions of science and governance.

To me, these ways of problematizing the idea of engagement indicate a long overdue shift away from conceptualizing communication between scientists and publics as “downstream” and “upstream” by questioning the definitions of science and of publics, and rethinking the directionality and linearity of those two streams. I aim, in the sections and chapters that follow, to attend to some of these calls to action in several ways. For instance, I will address the idea of engagement from where publics are rather than where we imagine them or want them to be. I will also examine the relationship between engagement as exchange and engagement as interaction in anticipation of building bridges between the two.

### *Engagement as Interaction*

In informal science learning circles, engagement is “a loosely defined term generally referring to behaviors that demonstrate interest in or interaction with a science-related activity or experience” (McCallie et al., 2009, p. 20). In this field, engagement is a buzzword, used in so many ways it has all but lost its meaning.<sup>9</sup> What meaning it retains is often closely related to engagement in the field of education (Appleton, Christenson, & Furlong, 2008), namely, the involvement of audiences in their own science learning. While these two definitions of engagement, that of

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<sup>9</sup> See (Bensaude-Vincent, 2014) for a rich discussion of the concept of public engagement as buzzword.

involvement in learning and that of democratic participation, seem to be only loosely related to one another, they find common deep roots in Dewey's writing on democracy and education (1916), and Freire's pedagogy of the oppressed (2000).<sup>10</sup> Ultimately, both uses of engagement embrace democratic ideals and attempt to level an uneven playing field.

Despite these important connections, the two forms of engagement have their differences.

Engagement in informal science learning does not necessarily require learning to be a "two-way street" in which scientists learn from activities in which the public is engaged. Rather, engagement here often indicates some kind of interaction in which the learners (the public) actively participate in their learning. Engagement as interaction might be seen as a way to involve learners in compelling or engrossing experiences without necessarily remedying the lack of two-way communication between scientists (or science communicators) and the publics with whom they are engaging.

Though these are different ways of approaching engagement, they are not mutually exclusive. Several authors have approached engagement as an encompassing concept. Rowe and Frewer (2005) describe engagement as three concepts: public communication, public consultation, and public participation. In their conceptualization of engagement, these three facets each represent a different relationship between publics and scientists.

Work to bridge the two cultures of engagement has been done by the Center for the Advancement of Informal Science Education (CAISE). The Center released a report in 2009

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<sup>10</sup> Further connection between democracy, education, and theatre can be found in Boal's *Theatre of the Oppressed* (1979).

examining possible connections between PES and ISE (Informal Science Education) (McCallie et al., 2009). The report identified the differences between PES and the use of the term engagement in much of informal science education, and aims to find ways to incorporate PES thinking into ISE endeavors.

The incorporation of PES mechanisms and perspectives into ISE creates the possibility for ISE organizations to operate not only as storehouses and/or disseminators of knowledge, but as facilitators of the production of new knowledge and understanding through dialogue and interaction among publics, scientists, and policy makers. The integration of PES mechanisms and perspectives into ISE positions informal science education as a contributor to broader cultural change, fostering increased awareness of science and a sense of shared responsibility that leads to civic participation in science and decision making. (McCallie et al., 2009, p. 13)

Though fraught with problems, the impulses behind both engagement as exchange and engagement as interaction take steps to create a better relationship between publics and science. Engagement as exchange, in its best light, seeks not only to better “sell” science to the public, but also to create conditions in which the public plays an active role in shaping the discourse around science and science policy. Similarly, engagement as interaction invites science learners to play a role in shaping their own understanding of scientific concepts and embraces democratic approaches to learning.

### **Engagement and Experience**

Thus far, this discussion has been limited to the concept of engagement as it has been defined within the fields of science communication and informal science education. But other fields have

defined and discussed engagement, including human computer interaction (HCI), the field from which the theoretical and methodological backgrounds of Frontstage originate. While design and its connection to my work in science communication are discussed in greater detail in the next chapter (as part of discussion of methodologies employed), I want begin to open the conversation about the relationship between PES and HCI here. User engagement, as it is discussed in the HCI literature, has some common threads with PES, but the most prominent discussions in the field attempt to narrow and refine the definition of engagement so that it can be effectively measured. O'Brien, Toms, and their colleagues (O'Brien & Toms, 2008; 2010) assert that it not enough to focus on functionality or usability in software design (O'Brien & Toms, 2010), but that users also require engaging experiences. They define user engagement as “a quality of user’s experiences with technology [that] is comprised of attention, affect, aesthetics, novelty, interest, control, feedback, challenge, and motivation” (O'Brien, Toms, Kelloway, & Kelley, 2008). O'Brien et al.’s measurement tool, a survey derived from their definition of engagement, is based on theories of flow (Csikszentmihalyi, 2008), aesthetics (for example Jennings, 2000; Laurel, 1993), play (Rieber, 1996; Stephenson, 1967), and information interaction (Toms, 2002). An important distinction between user engagement and public engagement is that O'Brien and colleagues approach the concept of engagement as a cognitive state, while public engagement is often studied from a sociological or cultural perspective. More importantly, O'Brien et al. use the term engagement as a quality rather than a type of communication. In science communication, an activity is either an engagement activity (meaning it fosters exchange or interaction) or it is not. It isn't engagement that user engagement researchers are aiming to create, but rather, engaging *experiences*.

Dewey and Bakhtin show us that experience is as much a product of what the user brings to the situation as it is about the artifacts that participate in the experience. What this position implies is that we cannot design an experience. But with a sensitive and skilled way of understanding our users, we can design for experience. (Wright et al., 2004)

In HCI, discussions of experience vary widely. O'Brien and colleagues draw their understanding of experience largely from Dewey (1934), whose writing on aesthetics and experiences can be traced through pragmatic philosophy. This work on experience is complemented by several other but here I will focus on several conceptualizations that I find resonant with the kinds of work being done (or being attempted) in these case studies. First Suchman (1987) and then Dourish (2001; 2004) approached experiences through the lens of ethnomethodology, which is built upon Schutz's discussions of phenomenology, and deals with meanings made through action. Next, Wright and McCarthy, Blythe and others (Blythe, Overbeeke, Monk, & Wright, 2004; McCarthy & Wright, 2007), approached experience from a pragmatist aesthetic perspective, focusing on the emotional nature of experiences. Boehner, Sengers and their colleagues (Boehner, Sengers, & Warner, 2008) build on both of these perspectives to establish the principles of reflective design.

### **The Active Audience and the Encoded Text**

My own history as a scholar has been deeply shaped by audience studies, specifically, the commitment to what cultural studies scholars in this area refer to as "the active audience" (Ang, 1990; Livingstone, 2010; 2005; Morley, 1993).

Stuart Hall's theory of encoding and decoding (2001) from 1980 has been examined and critiqued for decades, but I return to this theory because I find several aspects of his formulation

of encoding and decoding quite useful as a means of expressing the kinds of interactions I observe between audiences and experts. Encoding/decoding is a useful construct for discussing the public/expert relationship because while it divides the production and consumption into two categories, it complicates these categories in meaningful ways that speak to the themes discussed here. Hall recognizes and attempts to make sense of both the production and consumption of messages; he recognizes the ways in which messages are encoded or decoded are complex and laden with ideological decisions; and finally, he provides an admittedly flawed framework for alternate ways of decoding messages. It is this focus on the different ways audiences can make meaning of a text that has the potential to enrich discussions of engagement. I want to provide a brief discussion of encoding and decoding, followed by an account of the way I engage with this theory throughout the rest of this dissertation.

Simply put, Hall's theory states that when texts are created, meaning is encoded into them by their producers. As mentioned previously, the term text does not just refer to physical, written texts, but to the created object to which an audience attends. The texts I refer to here include performances, presentations, exhibits, and anything else presented to an audience in any medium. Audiences then decode that text in the context of their own lived experience. According to Hall, audiences do not always decode messages as intended. Hall asserts that there are three ways a message may be decoded. Audience members may decode according to what Hall calls the "dominant-hegemonic" reading, which most closely resembles the intentions of the producer. They may also decode a "negotiated" reading, in which they accept a part of the intended meaning, or accept the encoded meaning to a certain degree. Finally, they may take an oppositional decoding and reject all that the producer has intended. Hall notes, importantly, that



the three ways of decoding messages are to be considered along a continuum rather than discretely.

Although audiences may negotiate meaning or may take an oppositional reading of an encoded message, the processes of encoding and decoding are not balanced, nor are they neutral. Morley (1993) details the premises on which the encoding/decoding model are based: an event can be encoded more than one way; all messages are polysemic; and “understanding” messages is not as simple as it seems. The clear recognition that encoding and decoding are not balanced and the examination of the non-neutrality of the communication process are perhaps the most interesting aspects of Hall’s model. Encoding is political, and what is encoded into a message is far more than merely the understanding of the literal meaning. Similarly, the decoding process is fraught with complex patterns of sense-making rooted in personal and cultural experience.

Much of the empirical work done on encoding and decoding thus far is focused on the decoding of messages. Morley was the first to attempt a large scale study of both the encoding and decoding processes (Morley, 1980); however, his study, the *Nationwide* project, focused much more on the how groups from differing socioeconomic backgrounds would decode stories from *Nationwide*, a British news program similar to Nightline. Studies of the encoding process are limited in part because it is very difficult to directly observe encoding, especially in mediated contexts in which dozens, if not hundreds, of people are involved in the creation of messages. But beyond the practical limitations, theoretically, there are several issues that make studies of encoding difficult. First, the boundaries of the encoding process are murky at best (Wren-Lewis, 1983). For example, the role that television, as a medium, plays in the encoding process is

largely ignored. By treating television as a mechanism for reproducing messages rather than producing them, Hall fails to consider that the experience of watching television itself has an impact on how messages are received, or decoded (Ang, 1996; Wren-Lewis, 1983). Closely related problems exist concerning the “dominant-hegemonic,” or preferred, reading. Who decides the preferred reading? How? Additionally, Hall does not distinguish between “preferred reading” and “preferred meaning,” making it difficult to think about encoding without placing realist assumptions on constructivist paradigms (Pillai, 1992).

Despite its shortcomings, Hall’s encoding and decoding model is helpful when thinking about the relationship between the creator of the text, the text itself, and the audience. Differentiating between these three factors in a presenter/audience relationship provides a way of talking about each factor separately, and about the attitudes, beliefs, ideologies, etc. that become a part of the message to the presenter and the members of the audience.

### **Crossing the Streams**

In addition to looking at upstream/downstream relationships in different disciplines, these disciplines can often intersect, creating scenarios in which participants are both experts and publics, and communication between them goes upstream and downstream at the same time. For example, the second case study, *Emergence*, was developed with faculty from the theatre and physics departments, and the physicist and director who worked on the project were moving between different kinds of knowledge and trying to collaborate as both an expert and a novice at the same time. This is a situation in which there are multiple experts and multiple publics. In this example, the artist and scientist working together need to learn something about each other’s

work in order to complete the project. They are both publics in the others' field of expertise at the same time that they are experts in their own. In Frontstage, the experts who were presenting information to the public were new users to the Frontstage system, and their audiences were their public, but they were also our users.

The complexity of the relationships in these cases allows for exploration into questions about encoding and decoding and the nature of the relationship between audiences and experts, the ways social worlds collide or combine when collaborations cross boundaries, and finally questions about how encoding and decoding are changed in these strange social worlds or collaborative spaces.

First, I will address questions about the collaborative process in the arts and sciences, and about the nature of the social worlds surrounding art/science collaborations:

- What does the boundary work done in these projects look like?
- What kinds of objects or artifacts are created and how are they used?
- What are the implications for the creation of an art/science boundary world?

Next, I will address questions about the relationship between audiences and presenters in these cases:

- What can these moments where audiences and presenters come together reveal about both public and expert perceptions of relationship between audiences, experts, and the text?

- What relationship do these interactions have with the conceptualizations of engagement as exchange and engagement as interaction discussed here?

Finally, I will explore the relationship between questions about audiences and experts and questions about artists and scientists:

- How do boundary crossing collaborations impact the way presenters conceptualize publics?
- How do audiences conceptualize their roles during presentations that cut across different social worlds?
- What can these specific relationships within these mixed social worlds tell us more broadly about the expert/public relationships? About engagement?

### **CHAPTER 3: METHODOLOGY**

While each case discussed in this dissertation involves slightly different methods, it is important to describe the epistemological and methodological assumptions upon which these methods are hung in order to understand how the methods are related to one another. Additionally, it is important to understand what impact the role I play as the researcher (and practitioner or designer) plays in each of these cases. Finally, there are strengths as well as limitations to each of these studies, and even though they are three very different projects, there are ways in which they do not cleanly overlap to form a whole picture. This chapter will discuss the overarching themes woven into the choices I make as a researcher; how my background and my role as a subject in my own research inform those choices; and finally, the strengths and limitations that are embedded in the methods and methodologies employed in this dissertation.

There are many established methodologies similar to those employed here; however, none of them are a perfect fit for describing what I have done or why I have done it. The methodologies I use draw upon the traditions of participant observation and ethnography, audience studies, research through design, and, to some extent, participant research and activist research, to build a way of understanding both encoding and decoding processes in a variety of situations involving live audiences. My dual roles as researcher and practitioner (or in the last case, researcher and designer) might be the defining characteristic of the methodologies employed in this dissertation. While these roles complicate the already complex and nuanced nature of qualitative research, I believe the rewards are great. First, in having such an intimate role in the projects, I have been able to closely observe the processes involved in their creation, and been witness to nuanced relationships between the creators. This unfettered access was granted because I was a part of the

project. Second, my role in creating the texts and materials for these audiences provides a unique perspective on the way these texts are encoded and the way these interactions are designed.

Rather than trying to understand what the creators of these interactions intended from the outside, I took part in the struggle to engage with an audience, and encountered the pitfalls and roadblocks practitioners must face when they earnestly set out to create something of value. As a detached observer, it is often easy to be cynical of such efforts, and often losing that detachment brings accusations of “going native.” But the value of “being native” (Brannick & Coghlan, 2007; Kanuha, 2000) in these cases is that I cannot rest with critique, I must forge through the critical examination of the situation toward solutions. Where many scholars have critiqued the two culture divide or the engagement model or other forms of status quo, I will be able to take that next step and enact potential solutions.

Because I was deeply connected to each of the projects described here, I would not have been able to participate fully as an audience member. This is especially true in both the *Dance of Scales* and *Emergence* cases, in which I not only participated in the development, but was a member of the creative team. There is a raw-ness about having one’s own artistic impulses displayed for an audience that prevents one from sitting in that audience and seeing what other audience members might be seeing. For each of the cases, I could sit in the audience and observe the performances or I could use Frontstage along with the rest of the participants. However, I could not separate from my role as a practitioner, and even when audience members did not know I helped shaped their experiences, I could never experience the products of my research as they could. This is not to say that I cannot identify with audiences just as well as I do with practitioners; I have certainly been an audience member more often than I have been a producer.

But the ability to identify with an audience in the abstract is quite different from identifying with a specific audience at a specific performance.

The difference between studying the creative process and studying the audience's experiences goes beyond my personal abilities to separate myself from the performance: the time audiences spend with the products we create is fleeting, and their experiences are much less a part of them than they are for those of us who spent months building the presentations. Thus, there is an imbalance in the raw material to analyze and interpret when trying to understand the dynamics between presenters and audiences. This imbalance means that my research on how audiences made meaning from these productions and presentations does not match the depth and breadth of my understanding of the processes by which the presentations were created. That imbalance does not render audience research less valid, or less valuable, than production research, but I must admit the audience research is less complete, and lacks the "thickness" of my observations of the creative process. To adequately explain both kinds of research, the rest of this chapter is broken into two sections. The first discusses the participant observation employed in the development of each of the products for these cases. The second focuses on methods used for collecting information about the use and decoding of these products and presentations by audiences. I separated these two methods so that I could better articulate the processes through which I collected data; however, I do not consider the two separate forms of research as separate sets of data. Rather, the two kinds of research will be used to present the fullest possible picture of each of the cases.

## **Producing Research/Researching Production**

### **Participant Observation**

Participant observation is a broad term that defines a spectrum of relationships between the researcher and the research. Lofland et al. (2006, p. 17) define participant observation as “the process in which an investigator establishes and sustains a many-sided and situationally appropriate relationship with a human association in its natural setting for the purpose of developing a social scientific understanding of that association.” Jorgensen (1989) lists seven characteristics of participant observation. Participant observation 1) is interested in meaning and interactions from the perspective of an insider, 2) is situated in everyday life situations, 3) emphasizes the interpretation of human existence, 4) adopts a flexible process of inquiry that is constantly being redefined, 5) utilizes an in-depth qualitative design, 6) involves the performance of a role and the establishment and maintenance of relationships with participants, and 7) uses direct observation along with other methods of data collection (pp. 13-14).

The term participant observation comes out of fieldwork after Malinowski, who encouraged “going native.” Malinowski’s approach broke with previous anthropological methods because it focused on everyday interactions rather than structured interviews<sup>11</sup> (Dewalt et al., 2000). Over time, participant observation has come to define a range of activities from pure observation to complete participation. Dewalt and colleagues discuss a continuum that includes “nonparticipation,” “active participation,” and “complete participation.”

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<sup>11</sup> It is beyond the scope of this dissertation, but this form of fieldwork is closely linked with, and developed as a result of or resulted in the development of functionalist theory (Dewalt et al., 2000).



Participating allows the ethnographer to “know” in a unique way because the observer becomes a participant in what is observed. At the same time, however, our attempts to remain observers of actions and behaviors maintains a certain distance between us and the people we want to “know.” (p. 263)

Though Dewalt et al. separate the degree of participation from the degree of emotional involvement of the researcher, others who discuss participant observation (M. S. Schwartz & Schwartz, 1955) say these two aspects cannot be so easily separated. Researchers immerse themselves in the culture, but also go beyond participation to adopt a particular standpoint that reflects a mixture of their past experiences and background and their new experiences within the culture they are researching.

But the kind of “going native” Malinowski calls for is slightly different when doing research within one’s own culture. Kanuha (2000) calls researching a particular culture or sub-culture to which one already belongs insider, native, or sometimes indigenous research.

The native researcher often arrives at a project from an emic perspective. Emic suggests a subjective, informed, and influential standpoint, contrasted with an etic perspective that is more objective, distant, logical, and removed from one’s project [(Headland, Pike, & Harris, 1990)]. Therefore, the native researcher chooses not only a project in which she is deeply situated, whether by geography, tradition, or simply “inside” experience, but also one in which she is invested in those factors and others as they inform the “act” of research. (Kanuha, 2000, p. 441)

No doubt researching a culture in which you are already a member is wholly different from joining a culture and learning to participate as a member. Often, there is an activist component to

this kind of research. In Kanuha's case, she is a social worker who is also a lesbian whose grandparents were Japanese. She belongs to social and cultural groups which have traditionally been dramatically under-represented, and part of her work as an insider is to bring to light issues within this population that might be impossible to understand or speak about with necessary sensitivity and understanding as a traditional ethnographer or outside researcher.

In each case I present here, I was, in some way, a participant and an observer, playing various roles in the development of the projects and, occasionally, their implementation. I was deeply invested in these projects, approaching them from an emic perspective. But there are two significant differences between the classical anthropological methods and their descendants and what I have done. Like Kanuah, I am already a native in my research; however, I am not immersed within a culture, as the cultural anthropologists I cite above usually were. Instead, I am working within a collaborative endeavor that draws people from different (though not radically different) social worlds together. I was not immersed, full time, in a culture, but rather, I participated in a project for which I had a set role. While there was a deep cultural connection between us, our interactions were punctuated. This brings me to the second difference between my work and participant observation as discussed above: the specific and unique role I played in these projects. I was instrumental in the conception and played a leadership role in developing the projects. This role was natural for me: it was the same role played in my life as a practitioner prior to becoming a researcher, and it is a natural extension of the very questions that drove me to research in the first place. However, in much participant observation, and in much research undertaken from the perspective of one who is already native, the aim is to speak from

marginalized or ill-understood perspectives, not from a position of power, or of assumed power, which was the position I occupied as a co-creator and producer in these experiences.

### **Cultural Probes and Research Through Design**

Just as I occupied a privileged and interested position as a participant observer in the development of the two productions developed for the first two case studies, I took on a formative role as designer for *Frontstage*, and the approach to conceptualizing and realizing *Frontstage* was motivated by similar ideals and goals as my work on *Dance of Scales* and *Emergence*. I began to incorporate design methodologies into my thinking as a participant observer early in my work as a researcher. One of the primary ways I blend my research methodologies and my design methodologies is with extensions of interventions called cultural probes (Boehner, Vertesi, Sengers, & Dourish, 2007; Gaver, Dunne, & Pacenti, 1999). A cultural probe is a series of whimsical prompts designed to spark reflection, conversation, and imagination. Cultural probes have been used primarily to help designers gain an understanding of the populations for whom they are designing and to draw inspiration in their work as designers for these populations.

Gaver and his colleagues first used cultural probes in a design project commissioned by the European Union to raise the presence of the elderly in several communities in Europe. The seniors in the communities completed the tasks and sent the probes back to the design team, who used them to guide their design decisions. The probes were packaged in a small envelope that included some cards, a disposable camera, and a few instructions. The instructions, or prompts, asked the participant to complete different activities, such as responding to quotes written on the

cards, taking photographs of abstract ideas, (e.g. take a photograph of something that makes you feel lonely), and drawing maps. Each activity was directed, but also left open to interpretation. Through the probe, Gaver would get to know members of the community and thus would be able to better serve their needs when he designed for them.

Probes have been adapted in many ways and variations on Gaver's original cultural probes have become essential to many in the field of human computer interaction (HCI). Some of these adaptations of probes have become problematic for the initial designers (Boehner et al., 2007; Gaver, Boucher, Pennington, & Walker, 2004), whose concerns focus on the use of probes as quantifiable data or as ethnographic evidence. The probes, they say, embrace uncertainty, and are meant to subvert normal relationships between users and designers by providing opportunities for users to engage with ideas in unexpected ways. My own adaptations of probes have focused on extending them not in terms of what they can do, but of who can benefit from them. Several years ago I began adapting cultural probes to use them as ways to invite collaboration among diverse groups (Halpern, 2012). I introduced such probes into both *Dance of Scales* and *Emergence* to help build the collaborative relationship among the creative team. I write more specifically about the probes I developed in Chapters 4 and 5, when I describe these cases, and I refer to them as "boundary probes" because they were designed not to make culture visible to the designer, but to explore the boundaries between divergent groups, and, potentially, to help them develop boundary objects to help them collaborate (Halpern et al., 2013).

My extensive work with the probes has helped me bring design methodologies into the research process, a practice I have found invaluable as a way of generating insights I might not have had

otherwise. While I used these design methods in conjunction with qualitative methods like participant observation, they served a unique purpose in the process. As Boehner et al. (2007) suggest, the probes do not act as straightforward mechanisms for data collection, but rather are “designed to disrupt expectations about user research and allow new possibilities to emerge” (p. 1081). The original impetus for Frontstage was to continue this pattern of introducing whimsical, playful approaches to interacting but to use such endeavors to find the unseen dimensions of the relationship between presenters and audiences. Thus, I set out to create a sort of digital cultural probe for audiences that was similar to the boundary probes used in *Dance of Scales* and *Emergence*.

The same sense of designed ambiguity and play was deeply embedded in all three projects. I established two goals as I developed Frontstage. First, I hoped to design an open system for audience participation that would provide richer experiences for audiences and richer information for presenters. Second, I hoped that by observing the way presenters chose to use the system I would learn something about the relationships between the audiences and presenters. These two goals meant that the development of Fronstage was both a design problem and a research question. Such duality was not unlike grappling with the twin roles of researcher and practitioner in *Dance of Scales* and *Emergence*. Such an approach has been discussed by a small fraction of the design community, and has been named research through design, or RtD (Gaver, 2011a; 2012; Zimmerman, Forlizzi, & Evenson, 2007; Zimmerman, Stolterman, & Forlizzi, 2010). This developing method for thinking through design and research problems is still largely open for discussion, but several designer/scholars have begun to debate what RtD should look like in the HCI community. While Zimmerman and colleagues (2010) call for RtD to be

developed into a strongly structured, systematized methodology, Gaver (2012) advocates a more open-ended approach, in which design as a method has the potential to be a freeing agent in the research process; a chance to draw upon one's imagination and experience, while being rigorous in one's approach. In either case, "RtD allows researchers to rely on designerly activities as a way of approaching messy situations with unclear or even conflicting agendas" (Zimmerman et al., 2010, p. 310).

Thus far, RtD has focused on research on design (design research, or research about what designers do) or research for design (research that helps develop design implications, or better methods of design, or leads to better designs). I believe there is room to open this new space further, by using design to do research on or for other things. In the case of Frontstage, then, design as a method to explore the relationship between audiences and presenters, a theme that is no doubt relevant to design, but extends beyond the design world. Importantly, I hope this crossover will be the beginning of design as a valid and valued method of inquiry in other fields. In this instance, I hope design will inform science communication so I am advocating RtD as a way of beginning an open ended research question with a design problem. In this case, the research question is broad and asks how experts and audiences conceptualize their relationship with one another and how that plays out in their interactions. To develop an answer to this question, I begin with a design problem: to build a new audience participation platform that will allow me to explore the question. Zimmerman and colleagues (2007) describe four criteria for evaluating RtD projects: process, invention, relevance, and extensibility. In cases in which RtD can be used to examine a social or cultural phenomenon rather than seeking further understanding of design, the fourth criterion, in particular, is essential. The insights about

different kinds of connections sought through Frontstage can help not only future designers aiming to build participation systems, but also presenters, who have access to new tools for understanding and achieving their goals for a presentation, and researchers who can build on these insights into presenter motives and connections to develop a new model of how audiences and presenters interact.

In some sense, this idea is already embedded in reflective design (Sengers et al., 2005) which advocates the idea of technology as a probe to use “built systems analogous to the way a social scientist uses an experiment” (p. 56). Sengers and her colleagues developed reflective design to incorporate several different design perspectives, like critical technical practice (Agre, 1997), ludic design (Gaver, 2002), the use of ambiguity (Gaver, Beaver, & Benford, 2003), critical design (A. Dunne, 2008; A. Dunne & Raby, 2001), value sensitive design (Friedman, Kahn, & Borning, 2006), and reflection-in-action (Schön, 1983) into one practice in which it is not just the users who are considered, but also the designers themselves. Their discussion of reflective design yields six design principles and six design strategies (both lists taken from Sengers et al., 2005).

### *Reflective Design Principles*

1. Designers should use reflection to uncover and alter the limitations of design practice
2. Designers should use reflection to re-understand their own role in the technology design process
3. Designers should support users in reflecting on their lives

4. Technology should support skepticism about and reinterpretation of its own working
5. Reflection is not a separate activity from action but it is folding into it as an integral part of experience
6. Dialogic engagement between designers and users through technology can enhance reflection

### *Reflective Design Strategies*

1. Provide for interpretive flexibility
2. Give users license to participate
3. Provide dynamic feedback to users
4. Inspire rich feedback from users
5. Build technology as a probe
6. Invert metaphors and cross boundaries

The relationship between audiences and presenters, or, more broadly, between experts and publics, may be approachable as a design problem rather than a science or social science problem. This does not mean we should not search for solutions, but rather, that these solutions are not standardizable; are found in interpretive strategies and on-the-fly dynamic assessments of different situations. Still, the heart of the problem remains the same in cases that go far beyond those discussed in this dissertation. What can we ask of an audience or public? What do we expect of them as they engage with a text?



Research of the kind done here often includes reflection about the role of the researcher. At times, I held back from sharing my opinions. For example, in the case of *Frontstage*, I felt that my role as a participant was to shape the tool itself. Therefore, when I trained presenters in how to use the devices, I refrained from offering any opinion about how the system should be used. I was eager to see what presenters would make of it without my further intervention. In *Dance of Scales* and *Emergence*, my role was somewhat more complicated, as the balance between researcher and practitioner was not so neatly divided. I was implicated in the product of each of the collaborations, and so I had the impulse to ensure that they were strong productions. My understanding of the role of science communication and the role of performance informed my opinions of what would make these performances successful, and, often, what might have made them enjoyable, was not the same as what would make them engaging.

Throughout the accounts I write of each of these cases, it is important to view my perspective as both partial and privileged. I was one of a group of collaborators, and, as such, I had my own interpretation of what transpired during the collaborative process. Though I often created archival materials in the form of field notes, recordings, and photographs, the lens through which I view these materials is skewed; I interpret them as a practitioner and a researcher, so my hopes and fears are encoded into my understanding and memory of what happened. I want to be as transparent as I can about this throughout these accounts.

### **Learning from Audiences**

Even when my research required more traditional methods, the complexities of trying to understand someone else's experience and to produce knowledge about a subject from those

understandings were not lost on me. As I suggested above, my formative role in the creation of these projects precluded me from understanding what it was like to experience them as an audience member. Though I could sit in the audience and observe them and share their experience, sharing the space with audience members as they watched or participated in the projects was much less about my own reflections and more about what I gleaned from the rest of the group. Thus, research conducted on the consumption of these projects was quite different from that of the production. Most of my audience research might be categorized as ethnographic to the extent that audience researchers like Ang, Morley, and Hall (Ang, 1985; 1996; Hall, 2001; Morley, 2004) considered their work ethnographic. Audience studies scholars advocate ethnography because it is a way to engage with informants as they are experiencing events and to understand these events in context. The term ethnography calls to mind the traditional anthropological method of extended field observation of a culture foreign to one's own. This is not quite the case in audience studies. For audience researchers, ethnography usually entails in-depth audience interviews, often in groups, and often with some participant observation (Ang, 1990; Seiter, 1999; 2004). In addition, traditional ethnography often (but not always) attempts to study culture as a whole, while audience research attempts to understand one aspect (e.g. television viewing) of culture (Seiter, 1999). However, ethnography is an apt word because this research attempts to understand texts as they are situated within peoples' lives.

This unorthodox definition of ethnography reveals what audience researchers find methodologically valuable: understanding the way an audience makes meaning from a text within a context. By calling their work ethnography, they remove their research from survey-based research aimed at getting at what audiences think of a text. They move toward the kind of

methods that treat audiences as situated, and their consumption of texts as complex and utterly tied to their lived experience and the context in which they experience the texts. Audience studies scholars may be using the term ethnography a bit more loosely or in new ways, but this does not mean they are making methodological decisions lightly or without rigor. Researchers in this tradition have done much work to explain how they have made sense of their methods, and, though they have not always been received well in the broader fields of media studies and communication, the importance of their work, and their methods should not be ignored by communication researchers who want to examine the ways audiences make sense of the texts they encounter.

For audience researchers, methodology is a political choice. For Ang (1996), the use of interview and other qualitative methods is an integral part of a critical to approach empirical evidence.

The term ‘critical’ as I would like to use it here refers first of all to a certain intellectual-political orientation towards academic practice: whatever its subject matter or methodology, essential to doing ‘critical’ research would be the adoption of a self-reflective perspective, one that is, first, conscious of the social and discursive nature of any research practice, and, second, takes seriously the Foucauldian reminder that the production of knowledge is always bound up in a network of power relations (Foucault, 1980; Ang, 1996 p. 36)

Thus, the move toward ethnography allowed audience studies scholars to incorporate these networks of power into their thinking and to explore them while doing their research. As a political move, this also separated them from uses and gratifications research, a distinction they were eager to make (Ang, 1996; Livingstone, 2010; Morley, 2004).

One of the primary foci of this audience ethnography is speaking to audiences through interviews either individually or in groups. One of the complexities of this is that the interview itself becomes a part of the meaning making process for the audience members, and necessarily impacts the way they make sense of what they have seen. How, as a researcher, can I draw out meanings audiences make from the text rather than the interview? Certainly they are making meanings from the interview. As Ang notes, “What people say or write about their experiences, preferences, habits, etc., cannot be taken entirely at face value, for in the routine of daily life they do not demand rational consciousness; they go unnoticed, as it were” (Ang, 1985, p. 11).

Similarly, Seiter (2004) reflects on what it means to speak with audience members.

We cannot assume that what subjects say in an interview reflects individual, idiosyncratic views, or that what is spoken is all there is to be said on the subject. First, our subjects may not have access to all that might be going on with their media consumption, because of the role of the unconscious. Second, media tastes do not simply reflect identity, but are actually constitutive of it. Therefore, one of the things we would expect to hear from subjects is the reiteration of certain prior existing discourses on the self, society, politics, and gender. (p. 474)

Ang (1996) suggests researchers treat the interview itself as a text, and perform a textual analysis to understand some of the meaning making that has gone on. Morley also finds that semiotic interpretations of the text of an interview are important (Morley, 2004). The point here is that in order to make some sense of the relationship between the audience and the text, we need to carefully consider an interview as its own entity, with its own unspoken implications.

Focus groups retain most of the deep-rooted issues found in individual interviews: they are still highly constructed environments, and it is still impossible to remove the researcher from both the interpretive role and as a presence in the room. Beyond this, Lunt & Livingstone (1996) admit that group dynamics may cause group members to work to build consensus, especially in cases like the Morley's study of the British television program *Nationwide*, in which participants were in groups they already knew. Morley's answer, they say, is that this may be true, but it is also true in their everyday experiences, and so it doesn't invalidate results so much as it attempts to mimic participants' lived experience.

To me, this seems to strike at the heart of much methodological debate: do we, as researchers, attempt to strip away "variables" to isolate phenomena, or do we attempt to describe the world as we see it, knowing our descriptions are situated, imperfect, and incomplete? By choosing the road of ethnographic and interview data, and attempting to describe complex meaning making processes, I have already made a commitment to the latter. Understanding that group dynamics are a part of a group interview and observing those dynamics can further inform research, rather than muddle it: "The question of how homogeneous or heterogeneous a culture or subculture is may also be regarded as something to be investigated" (Hojjer, 2008, p. 281).

For my work, the understanding the use of focus groups in market research illustrates an interesting double-edged sword. Though the co-opting of a method that is devised within an explicitly political research agenda (Ang, 1996; Press, 2006) may make audience researchers uncomfortable, focus groups have been used in science communication research for similar reasons: to find "what works." And, in part, my work is no exception. This attempt to use the

information garnered in research to improve texts and tailor them to the wants or needs of audiences is perhaps the most problematic difference between my own work and that of audience studies researchers like Morley, Ang, and Seiter. It might be easy to dismiss goals to learn from audiences to make more engaging texts as abhorrent to scholars who devote much of their energy to exploring the power dynamic between producers and consumers, but I think that even these scholars would agree that there is a difference between market research to find out “what sells” and public engagement research aimed at finding “what engages.” On the other hand, my work is predicated on the assumption that scientific knowledge is good, and that there is a public benefit to exposure to scientific messages. Research based on these assumptions might be received as a way of twisting audience studies to use the field as a justification and method of market research in the name of public good. I maintain that the aim of many science communication researchers, myself included, is to help remedy the clear imbalance in power between the public and those who create scientific knowledge, rather than to take advantage of that imbalance to better “sell” science. I acknowledge, however, that my role in shaping the conversation both as a practitioner and as an interviewer is significant, and reflection on that role throughout the process of gathering and analyzing audience responses will help put audience interviews, observations, and focus groups into perspective.

## PART II: CASE STUDIES

The following cases trace the trajectory of my two research themes. *Dance of Scales* began as an inquiry into the nature of art/science collaboration, but throughout the process, I found to understand this collaboration, I had to examine the ways the artists and scientist involved thought about their audience. *Emergence* delves more deeply into the ways the collaborative teams thought about their audiences, and the way audiences responded to both narrative and participation. Finally, the examples in *Frontstage* move away from art/science collaboration to focus entirely on how artists or science communicators think about and incorporate audience participation into their endeavors.

*Dance of Scales* reexamines boundary work, and looks at the way boundary work shifts depending on when and how it occurs within the creative process. The boundary work in which Maren and Itai engaged became encoded into the performance itself, and an examination of the work they produced reveals a shift over time in the nature of the collaboration as well as the aims of the participants. Conflation of the way they characterize the kind of collaboration they want and the product they want to share with an audience is also apparent in the collaborative process and in the performance itself.

*Emergence* faced similar boundary discussions and the same work early on to create constructive boundaries. Through these two projects, patterns began to emerge. For example, in both projects, the epistemic authority afforded science was prioritized over the artistic elements early in the process, making room for different kinds of tensions later on. However, *Emergence* had a much more complex collaborative structure and performance than *Dance of Scales*, in part because of

the greater number of collaborators and their more focused agendas, but primarily because participation had a central role in the development of the project. The challenges of participation drew the relationships between these presenters and their audiences into sharp focus.

Finally, through the use of Frontstage, I examine, more thoroughly, how presenters conceptualize audience, not within the context of this new social endeavor that operates between social worlds, but in several different relatively typical situations. The breadth of interactions I was able to witness by giving presenters a somewhat blank canvas upon which to build their own ways of fostering participation further developed my thinking about the ways the different tensions I witnessed in the previous cases were illustrations not of the relationships between artists and scientists, but of the relationships between presenters and audiences.



## CHAPTER 4: *DANCE OF SCALES*

*Dance of Scales* began when a physicist and dancer who I had previously paired for a brief collaboration in 2008 asked to continue working together to create a full length performance. Planning began in February 2009, with a group of four collaborators: myself; Itai, a physicist; Maren, a dancer and choreographer; and Max, a producer with a background in science themed performances. The four of us worked together off and on for almost a year to develop the performance. During the development process, the team previewed the first section of the four-part show at a conference on informal science learning held by NISEnet (the Nanoscale Informal Science Education Network) in California in September 2009. After the September performance, development continued, as we created three additional sections to complete the now one hour performance. In November 2009, three additional dancers joined the team for the final performance, which was held in January 2010 in Ithaca, NY, at the Light in Winter Festival, an annual event celebrating science and art. The final performance consisted of dance, narrative, and multimedia elements: the content was drawn largely from Itai's work, and the focus was on how objects move at the nano-, micro-, and millimeter scales.

I did not begin this project as a researcher studying a phenomenon, but rather, as a practitioner, collaborating with a team who wished to create a science/dance performance together. I began seriously considering this a research project partway through the process, and in doing so, I became acutely aware of my dual role as a researcher and practitioner. That duality would deeply inform the project as well as the way I now write about the project. In some sense, I am accessing the data (recordings, notes, photographs) and my own memories as archival materials rather than as ethnography; however, my reflections are those of a participant observer/

ethnographer as these parts of me are now inseparable from my self as a practitioner. As I discussed in Chapters 1 and 3, my research methods were strongly tied to the methods we used to create the performance. In this particular case study, I sometimes felt conflicted about what to say during meetings, especially when Itai would express deficit-model thinking about how and why to reach audiences. In this case, I chose not to share my thoughts, believing it would inhibit the process if I were to introduce my scholarly work while we were in the middle of developing the performance. My training in science communication had prompted me to shun this type of thinking; however, for most scientists who communicate about their work, the aim is to teach audiences something they did not know before. Because I did not challenge Itai, I began to see that he operated from a desire to share ideas that moved him, and I came to recognize that drive as the same drive that motivates artistic expression. I wondered if this kind of enthusiasm could be separated from what we often believe is deficit model thinking.

Additionally, when we first discussed the possibility of attending the conference in California and presenting, Maren informed us that because she could not bring additional dancers, she would expect us (Itai, Max, and me) to join her on stage, and we had agreed. Now came the time to honor that agreement, so the three of us became Maren's dancers. Itai had planned to perform in the show from the beginning and relished the idea of dancing, but Max and I had not planned to perform. Though Maren danced solo or with Itai for the majority of the performance, Max and I would join them on stage for two small sections of the fifteen minute show. This was a horrifying thought for me, as I am not a trained dancer and have no desire to perform on stage in any capacity (and even dread giving talks or lecturing students because I am nervous in front of large groups). But, Itai, a physicist with no training in the performing arts, was willing, and even

eager to dance, so I felt I could not refuse. My own reaction made it increasingly difficult for me to understand why Itai would want to put himself in this position. I was engaged in my own form of boundary work, not between scientist and non-scientist, but between professional dancer and non-dancer-who-danced. I noted these boundaries in part because I found myself actively establishing them to protect myself from embarrassment, and perhaps to protect my autonomy as a researcher and a practitioner.

### **Creating *Dance of Scales***

The aims of the project were complex, and early on it became clear that there were many overlapping and competing reasons we had undertaken the project. First, Maren and Itai wanted to participate in a collaboration that would allow them to better understand one another's work. They had enjoyed their previous work together (see Halpern, 2012 for a detailed description of that project), and their personal relationship developed to the point that they wanted to work together for social as well as intellectual and artistic reasons. Another aim was to create a full-length performance using concepts from Itai's research to help communicate his work to broad audiences; another was to provide an opportunity for Maren to choreograph and dance; still another was to create a performance for the Light in Winter Festival. The annual festival is designed to bring together arts and sciences, and the Light in Winter producers who commissioned *Dance of Scales* wanted something that would capture the audience's interest, not necessarily teach them. My role as a collaborator was largely to facilitate, but my input was also required for technical, aesthetic, and content decisions. As a researcher, I aimed to gain a better understanding of how artists and scientists work together, and what their work means to

audiences, adding the goal of creating new knowledge about such a process. While it may seem initially that each of the objectives discussed above belonged to a specific participant, this was not the case. Each member of the creative team held multiple perspectives of performance goals and purposes in our heads simultaneously. To continue Gieryn's cartographic metaphor, the boundaries between our goals were soft, ill-defined, and there was much shared territory.

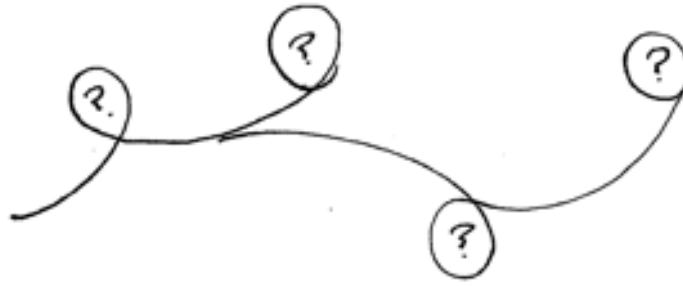
Over the course of the development of *Dance of Scales*, a tension arose surrounding the representation of dance and science within the production as well as the role each played in the process of creating the performance. The majority of this chapter will trace the evolution of this tension, how the actors' responses to it evolved, and how those responses transformed the production itself. Even though the initial boundary work done by Maren and Itai, along with boundary work they had done in their previous encounter, was largely collaborative and constructive, in moments when their easily established territories were encroached upon, they snapped into a mode in which they were protecting the autonomy of their domain, requiring negotiated solutions rather than agreed upon outcomes.

The four principle actors (Maren, Itai, Max, and myself) were eager to ensure the process and the product were handled fairly to the satisfaction of each member of the team; however, despite continued congeniality (these tensions did not become adversarial or confrontational) transforming the desire for fairness into reality proved a difficult task for all of us. As we began, we naively believed that the ideas and the process would organically provide a structure that we were excited about, remaining above any discussion of fairness or balance between art and science. We believed this, in part, because the first collaboration between Maren and Itai had

gone quite smoothly. During their first collaboration, the two of them developed an overlapping model for how they approached their work. Much of the conversation focused on the ways their process was similar, thus, the ten-minute performance they developed focused primarily on displaying the similarities between dance and science. Specifically, Maren and Itai described the process by which they did their work in terms of a circular pattern. They identified and mapped out three phases common to both art and science: observe, interpret, and share. They then developed a performance that would explain to an audience their understanding of the process and how it applied to both art and science. So, when they began their second collaboration, they began with a sense of shared territory in the form of process, and the idea that they could find parallels in the way that they worked.

This time around, early in the process, Itai noticed he was providing material to inspire Maren, but the act was not reciprocated. This was the first hint that their shared territory was no longer shared, but remained connected. This early concern grew over time, and, by the time we had completed the partial performance in September, Maren was also dismayed by the clear focus on explaining Itai's work, and asked for a part of the show that was *about* dance rather than featuring dance about science. These two concerns were slightly different, but spoke to the priority of science as the content and dance as the medium by which the content was delivered. Over the course of about six months, the landscape of the project had been remapped. Maren and Itai were in agreement that they were no longer comfortably operating within their previously shared territory. They were dissatisfied with an inequality they perceived in their map of both the process and the product they were developing, and they wanted to rethink the collaborative process.

In our discussions about this remapping, process and product were intertwined, and, to some extent, perhaps conflated, though it was apparent that we focused on process earlier and as we moved along and came closer to the performance, the focus shifted toward product. As I analyzed what we talked about, I discovered that “fairness” only captures one aspect of those conversations. Overall, I identified four different kinds of discussions throughout the process: integration, fairness, balance, and negotiation. These are not actors’ categories, they are categories I am imposing as a researcher revisiting the experience several years later to help sort out a complex relationship that shifted over time. I do not know if the actors were conscious of the shifts in our process. They did not explicitly speak about them, and I do not recall being highly conscious of the changes at the time. As I review audio and video recordings of meetings and rehearsals and revisit my field notes, the transitions over time appear clear to me. The shifts from integration to fairness, then balance, then negotiation stemmed from a seemingly irreconcilable difference in the underlying relationship Maren and Itai perceived with their audience: Itai’s goal was to explain, while Maren’s was to express. This chapter will end with a discussion of this underlying difference. The questions remaining at the end of the chapter are: whether or not that difference is irreconcilable, and whether it is a tension between these particular collaborators in this particular project, or part of a larger disconnect between these two social worlds.



*FIGURE 2: An image drawn by Maren during our first meeting.*

## **From Integration to Negotiation**

### **Integration**

The project began with a meeting in February 2009 between Maren, Itai, Max and me. Much of the conversation at the first meeting was about the concept of movement, largely because this was what Maren and Itai had in common—he studied fruit flies’ wing movements, among other things, and she danced. This meeting was largely brainstorming and free discussion. The meeting had two noteworthy outcomes. First, the creation of a thought provoking image and the discussion that followed, and second, the creation of a list of four questions that would serve as a guide for developing the show.

Maren drew this figure (Figure 2) on a chalkboard while trying to explain her view on how we think through questions in both the sciences and the arts. “There’s a question,” she said, “you study it, then that allows you to go this way, and, you know, and then there’s this thing that you study, and then you go over here and there’s this thing, and then you go over here.” She added “these are all questions.” Itai quickly connected this process of questions leading to other questions to his work. “Looks like bacteria,” he said. After initial laughter, Itai clarified, “That’s

what the bacteria are doing. They're asking questions. Each time they're tumbling, they're asking 'what chemical gradient am I going to go after, and which way is it strongest at?'" The figure struck me as highly meaningful and as a potential new boundary object for the team. It was clearly open to multiple interpretations, but, because we were all present at the moment it was created, it held a special significance for each of us, and the meaning we each made of the symbol. Though the image was largely lost later in the process, it seemed very important in this moment.

The exchange between Maren and Itai as this image was created is indicative of the early process: they saw parallels between their ways of engaging with the world and wanted to explore these themes. This was similar to the boundary work in which the pair engaged during their first collaboration. The two were looking for shared territory; overlapping space in their cultural landscapes or social worlds. Reflecting on the symbol now, I see it as a map for that territory. It was also a roadmap for what Itai and Maren hoped our collaboration would look like. I believe they hoped that each of those question marks would stem from a scientific or an artistic question, and that each question would inspire another question to be explored through dance or through science. Later, this loose structure that seemed to be organic (flowing naturally from art to science and vice versa) would give way to one that focused more on fairness. Here, I believe we all imagined that the performance would easily move between art and science, driven by ideas rather than an imposed structure.



The meeting also resulted in the creation of a list of questions that would guide the creation of the performance the same way research questions guide the design of a study. The questions were:

1. How do things move on different scales?
2. Why do things move on different scales? Or What drives movement?
3. What are the rules of movement? Are they different for different organisms and on different scales?<sup>12</sup>
4. How do we talk about these things? What kind of language do we use?

I believe these questions were also a part of the their shared territory. From this initial meeting, Max and I decided to develop a boundary probe for the team. I believed it would help us align our goals and provide a way of focusing our ideas for the show. Usually I introduced boundary probes to groups who had not worked together before to spark collaboration, reveal otherwise invisible dynamics and thought processes among the group members, and shape necessary boundary work into constructive dialogue. I had used boundary probes in several projects at this point because I found that they facilitate this kind of productive boundary work instead of the kind of contentious boundary work that arose when tensions between individuals' goals, reasons for participating, and preconceived ideas remained unspoken and unknown.

Because they had completed a probe in their first collaboration, Maren and Itai were familiar with the concept. They were already quite comfortable together, so the probe would not serve as

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<sup>12</sup> Rules would play a larger role in the discussion of this performance and in subsequent projects. The concept of rules becomes a recurring boundary object in this project and in *Emergence*, discussed in the next chapter.

a way to break the ice. I structured this probe around the series of questions they developed during the first meeting. Though I did not think specifically about it at the time, many of the prompts in the probe still asked the participants to chart their territories. Those that did not specifically task us with examining something through the lenses of dance and then physics, focused on expressing ideas through movement. The probe consisted of these seven prompts:

1. List the rules of performing dance. List the rules of performing experiments.
2. Move as if you were one foot taller. Now one foot shorter. Now move as if you were one nanometer tall. Now move as if you were the size of the sun. What was easier? What was more difficult?
3. Create a simple game of movement by establishing 3-5 rules.
4. Draw the culture of dance. Draw the culture of physics. Describe what you drew. Are there any similarities? Differences?
5. Tell the story of a discovery that prompted more questions. What were the questions? Were they answered? (no help from books or internet)
6. Draw how dancers work together. Draw how physicists work together.
7. Tell the story of this shape (they were given a copy of Figure 2) as it relates to dance. To physics. Now tell a story of this shape that could be about dance or physics.

During the probe, the two engaged in constructive boundary work, just as they had in their first collaboration. Thus, their interaction with the probe revealed both the differences and similarities in the way Maren and Itai approached their work, and what they saw as the core of dance and physics respectively.

ITAI: In physics the central thing is to essentially go after the sort of universal thing that should be repeatable in any lab. That's what we're centered around. What is dance centered around? What is it all about?

MAREN: It depends on who you ask. Dance is centered around communication between people, communication of ideas or of emotions, community, connecting. It might be around a political agenda, it might be entertainment...for me it is centered around communication and connecting people and creating community and making meaning. Meaning out of life or out of experience.

ITAI: How does dance make meaning?

MAREN: So what I mean by making meaning is that it has the potential to draw attention to interactions or moments that are just moments in life and they get passed by...you make visible a human interaction that is just small, and it happens all over the world at every moment. Somehow by noticing it draws meaning to an event.

MAX: Making the invisible visible?

Both Maren and Itai suggested that their work “makes the invisible visible,” and they found some common ground in that concept; however, to Maren, the act of working with others was ultimately one of the most important aspects of dance, while Itai recognized science as a social endeavor, but his goal as a scientist was to provide evidence to make “true” claims about the world. Maren also indicated that she believes dance is an exercise in meaning-making, not necessarily something that inherently has meaning of its own. The four of us would try to find common ground and feel out the limits of the intersection between science and dance throughout this early stage of the process.

The work with probes is indicative of the ways in which my work as a researcher was informing our practice. The probe was based on work I had done as a researcher, drawn from reading I'd done as an academic, and the aim of the original probes was to induce reflection so that designers could learn about those for whom they would design. Thus, the probe was a way of drawing out information about Itai, Maren, Max's, and my own beliefs and ideas surrounding the project, but, more broadly, surrounding art and science in general. The questions we asked were based on the first meeting, but they were developed with an awareness of a history of art/science tensions and struggles. Though the primary goal of the probe was to further develop the performance, an ancillary goal might have been to learn more about the practice and the participants, though at the time, I do not recall explicitly thinking or stating that I wanted to do so. The probe may have been a useful exercise, but with this more extended process, and these already familiar actors, it was not as central as probes had been in the past. At the end of the meeting during which we held the probe Maren asked, "What did we get out of this that's different from—that's more than the last meeting?" This opened a discussion of what happened next, and led me to wonder if the probe had had any affect on the process at all.

## **Fairness**

I found the meeting following the probe was more illuminating than the probe itself. This meeting was the first clear indication of what would become a long-term struggle for fairness between dance and physics, or, more specifically, between Maren's vision and Itai's. Much of the conversation during this particular meeting focused on the idea of "homework" and fairness in the creative process, though later discussions would focus more on the fairness or balance in the

performance itself. Prior to the meeting, Itai showed Maren some videos of small organisms moving, and she had tried to create movement based on those videos. Itai was focused on what the reciprocal assignment might be: If he gave her videos from which to create dances, what would she give him?

ITAI: There's dances on the different scales, but some ways those are sort of assignments that I gave you. Are there assignments you want to give me? Like, I mean I study dance on different scales, essentially. As a physicist, I study dance on different scales. You study dance, or teach dance, or choreograph dance, and then, you know. I'm trying to figure out, you know, what's the reverse? Does that make sense?

[Later in the conversation] So if it is your interpretation of the science I do, then it would be my interpretation of the dance you do. So the assignment would be to go the other way, you know, so you could show me a dance, I could do my sort of interpretation of what it is that I see and is that like filming you doing leaps and bounds and whatever and then trying to tie it in to something that I do? In terms of my analysis?

[Still later] The arrow is still pointing one way [...] and I'm wondering what it is that can go in the other direction.

MEGAN: So what your interpretation of her dance is?

ITAI: yeah something like that [...] and it doesn't have to be with everything, but it's sort of like giving each other assignments.

At this point in the conversation, this seemed to be an intractable but not hopeless problem. We did not dismiss Itai's question, but we did not have a concrete answer for him. We suggested that perhaps such an answer would come later, after Maren had created something for him to

interpret. Maren was hopeful that their work would lead to something new; something that was neither art nor science.

MAREN: That step comes a little later after I've done some work. So right now all the arrows go this way, then in a little bit, I have arrows going that way, and what results from both of the arrows crossing is something that maybe we don't understand, but maybe it's about communication, maybe it's about reaching an audience, maybe it's something larger than art or science, you know what I mean? Maybe it's not, but there's the potential for...you know, how I've interpreted you and how you've interpreted me. It illuminates something larger than maybe just this project.

Maren was not yet worried about fairness, even though Itai was beginning to raise some concerns. There was a sense that the process would follow the map Maren had drawn in the first meeting (Figure 2), but that rather than each question arising organically, there would be some turn taking. The next stem would begin from questions Maren is raising. Though Maren's hope, that they would find something that was neither art nor science, was connected to the idea of integration, this conversation showed the beginning of a transformation to fairness. Despite Maren's hopes, the map was shifting from questions and ideas that need not be art or science to questions and ideas that would be one or the other.

During these early meetings the four of us developed a structure for the performance that broke it into four sections. Each of these sections would focus on movement at a different scale in dimension, and we would begin working on the first section, movement on the nano scale, for

the performance in California in September. Maren would show us loosely developed ideas based on video or explanation from Itai and we would work through them together. Much of the conversation focused on providing material that would inspire Maren, or would express concepts like making the invisible visible. Doing this while also presenting scientific information about movement at different scales proved to be a challenge, and often we found ourselves gravitating toward creating movements that illustrated scientific concepts. We were constantly fighting against this, and attempting to create opportunities to put dance back into the driver's seat. But we were not able to find a clear way to do so. The earlier conversation between Maren and Itai about homework seemed to portend the kinds of difficulties we would have throughout the development.

After the first few generative meetings, activities to develop the show can be loosely divided into meetings and rehearsals. At first, the two seemed almost indistinguishable, though early in the process we set aside time during meeting/rehearsals to discuss grant proposals, and these conversations were far different from our conversations about the performance itself. During the rehearsal portion of meeting/rehearsals, we would often complete a series of physical and vocal warmups before engaging in discussions about the structure of the show. Both Maren and Itai would bring ideas into the room; and early incarnations of the "script" consisted of short scientific essays Itai wrote not to be read or performed for an audience, but to provide Maren with material from which to create movement. The meeting/rehearsals allowed us the opportunity to develop ideas rapidly. As we moved toward the first performance the two events would become more discrete. During meetings we would discuss issues with the script and discuss organizational details and technical needs. Meetings also became a place to engage in

more philosophical conversations about why we were making the choices we made. Rehearsals took on the traditional structure of sections of performance followed by “notes.” As more dancers joined the team, the rehearsal structure transformed once again, and not all members of the original team were present at each rehearsal.

## **Balance**

The September performance continued to push us in the direction of using movement to inform people about science in part because funding opportunities for such events generally come from organizations whose agenda is to promote science, rather than produce art. The chance to perform *Dance of Scales* at NISEnet was no exception. Our first performance of *Dance of Scales*, in San Francisco, was for a network of museums and science centers dedicated to informal science education. Though we did not collect data, the performance was anecdotally well received by the NISEnet audience. We also conducted workshops on using movement to communicate scientific concepts, which do not fall within the scope of this study. I mention these workshops because they help provide context. The entire performance was structured within an existing informal science learning social world, in which the performance itself was presented as a novel approach to do the work of that social world: to provide compelling interactions for informal science audiences.

When we returned to Ithaca and held a post-mortem discussion of the event, Maren indicated the lack of balance bothered her. Both Itai and Maren expressed their desire for a more balanced approach.



ITAI: Maren, you said that, for you the performance was, I mean this one was specifically science-based. And so for you, that balance was off, for what you'd like to achieve for Light in Winter.

MAREN: That's true. Yeah, so when we come back to Light in Winter, I was, you know, just thinking that it would be good to have a section where it doesn't really start with the science concept at all. It just starts with a dance concept, or some dance idea that is developed, and then we put the science in later. Or not. Or it's just "this is art" and art is next to the science, and people can make whatever connections they do. So that was, I knew going in to this that it would be science oriented and it turned out to kind of rub me more over time, and I don't know why I have such a thing about it.

This conversation revealed several things. First, this is the first time, to my recollection, we really spoke in terms of the balance of the performance itself. Itai used the term balance, and that, to me, marks a shift from earlier thinking, in which they attempted to integrate or to create a fair process. Previously, the idea had been that if Maren had homework, so should Itai; somehow they should both should have engaged in the same kinds of generative activities. After this point, it seemed more as if their work should result in roughly the same amount of stage-time during the performance. While integration suggested that the audience should see science and art at the same time, and fairness suggested some kind of natural flow between the two, balance meant that there was a true divide. In that meeting, Maren was asking specifically for a moment in the show that was driven by dance and need not be tied to science at all, explicitly dividing the show into science and dance. Now the act of balancing them meant adding to the one that is lacking until they were roughly the same.

Second, a discussion of the difference between what dance looks like and what science looks like on stage begins to emerge. Maren talks about people making whatever connections they want to rather than being directed toward particular understandings, which seemed to fundamentally rub against Itai's idea of communicating scientific concepts. His goal, like that of many scientists, is to clearly explain scientific phenomena so that everyone reaches the same understanding. As Maren continued, there was also a shift in the ongoing boundary work done by the four of us:

MAREN: But I think part of what we somewhat discovered in our rehearsals for *Light in Winter*<sup>13</sup> was that this is a festival of art and science, and part of it is that they're two different things, and they wouldn't be separate if there wasn't a different need for each of them in the world, and so I think it's important not to ignore that, and to me that means they can live side by side and not be enemies, and have a conversation, and maybe the conversation is things that don't connect, or maybe this doesn't relate to my world, or this does relate to my world but in this way, or, you know, so I think it's fair to process, to go through that and I guess for me dance doesn't, sometimes choreography doesn't have an overall through line. Sometimes it's just dancing and that's what it's for. I'm not saying we shouldn't have a through line because this is more than just basic choreography...

Previously the boundary work Maren and Itai had done pointed toward differences between art and science, but the primary focus had been finding the ways their two worlds overlapped. They had focused on process similarities and grand themes, like investigating the world. For the first time that I recall, Maren asserted that science and art are fundamentally different, and serve different needs in the world. Here, the boundary work at play resembled Gieryn's discussions of

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<sup>13</sup> Maren is referring to their previous collaboration, which was featured in *Light and Winter* the previous year.

boundary work much more than the early boundary work discussed above. Here, Maren is clearly protecting autonomy rather than developing shared understanding of the differences between art and science. This moment was illuminating because I saw clearly something that had been slowly happening throughout the creative process. There was a pulling apart of art and science, as opposed to the previous attempts to marry the two. It was as if there were too many skirmishes over their shared territory for it to continue to be comfortably shared, and now they were vying for that territory. There was still a larger map in which they believed they could coexist, but this new cartography allowed for neighboring pieces of the landscape of the performance, rather than co-owned spaces.

Itai was sympathetic to Maren's concerns, and had championed her need for dance to have its own moment. Early on, he'd advocated fairness in terms of homework, and now he was eager to make space for Maren. However, differences in art and science, or at least in Maren and Itai's aims, would make balance a much more complicated ideal than perhaps we realized. Early in the process, the discussion around what I have called fairness meant that dance and science were both valuable and central to the performance. There was no method or need for measuring their input/prevalence. This balanced approach would mean that there were two sides of the performance, and that they must fall into equilibrium. In these discussions, process fairness was less important than balance onstage. While this idea had been addressed before the September performance, the creation of an integrated piece was in the foreground. The imbalance in the September performance drove the idea of balance into the foreground as we developed the rest of the piece. At the same time, I sensed a shift away from the belief that the science and dance could be combined, that they could create something new, as Maren had suggested during the

third meeting. Though it was not worded this way, the new belief seemed to be that either science or dance were the focus of any given moment, and the aim was now to ensure equal time and weight. Maren repeatedly expressed the need for a part of the show to “just be about the dance.” Gone were the discussions about creating something that was both and neither dance and lecture, and new discussion revolved around what Itai had to explain and how much of the performance could be experienced rather than understood.

When the three additional dancers began to work on the project, the dancers outnumbered the non-dancers, there was a specific technical language the dancers used, and specific issues with choreography with which they grappled. As Maren worked more with the dancers, the need for Itai to dance had diminished, and Max and I were relieved to no longer be needed on stage at all. Itai now fell in to a role of narrator/lecturer. In the first section, he learned choreography and performed it. His physical interactions in the space and with the rest of us were well developed, and were somewhat complex. While that section of the show remained the same, in subsequent sections, he would be relegated to the role of scientist; only occasionally would he interact with Maren or the dancers physically, and when he did, it was for brief moments that were often improvised. He did continue to interact with them verbally, at times, to explain what their movements signified, but more often than not, he was interacting with the audience rather than the dancers. This transition lent itself easily to the idea of balance. Time on stage could either be used for dance or for explaining scientific concepts, but not both. The three dancers working with Maren were either working alone with her during a rehearsal (I often watched these rehearsals) or they were trying to learn from Itai to help them understand some of the movements the team had developed. These individual movements remained inspired by the scientific concepts Itai

explained; but broader combinations of the movements used to develop choreography became a kind of vocabulary for the dancers to play with as they created expressive moments.

Further cementing this new vision of balance, Itai brought in additional demonstrations in between moments of dance in which he was alone on stage embodying concepts he wished the audience to understand. In one demonstration, he held a large pair of “wings” made of foamcore and sat on a stool that spun to demonstrate how fruit flies manipulate their wings to steer while they fly. This demonstration was inspired by our work together, and developed collaboratively. It was so compelling and memorable that Itai reported using it in lectures long after *Dance of Scales* was over. In another demonstration, he used materials from his lab to demonstrate how viscous fluids can be “unmixed” when stirred backwards. Both of these demonstrations were exciting to watch and captured the audience’s attention. But even if the first example came out of our work together, the second was literally a demonstration he had done in classrooms.

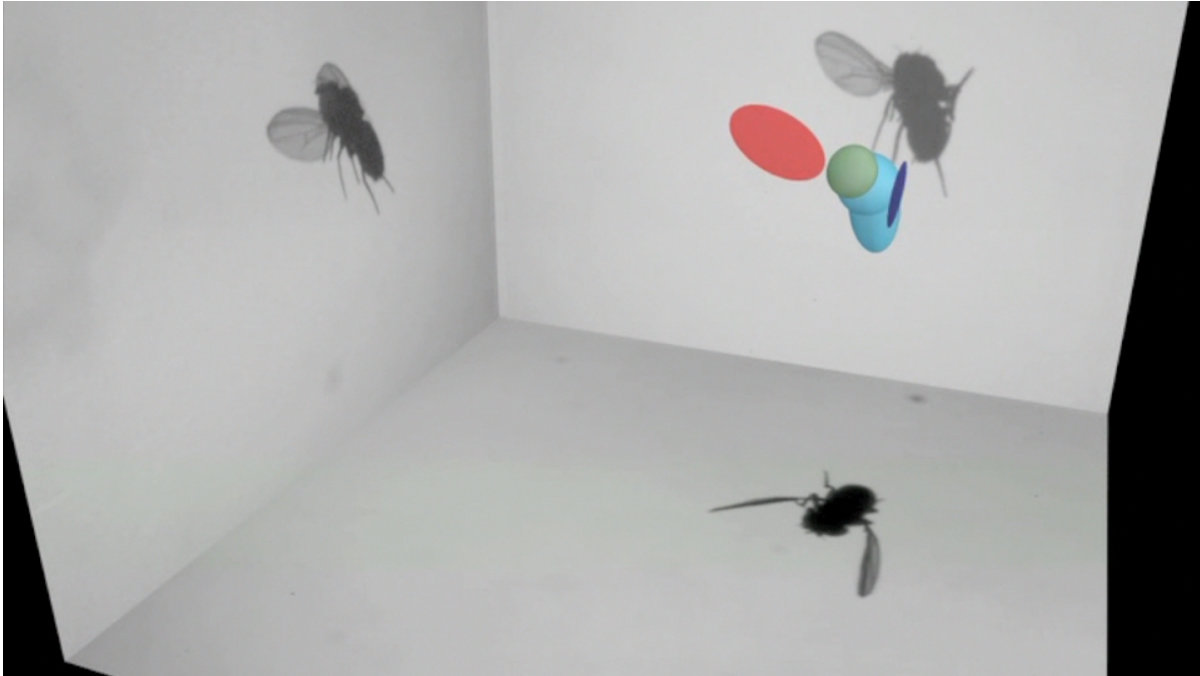
The remapping of their terrain was becoming visible in the production, and could be witnessed during the course of the performance itself. The first act, created before the NISENet performance in California, featured mostly Maren and Itai on stage together. They danced with one another while Itai spoke about the ideas they were presenting. Maren also spoke during this section, for a participatory moment in which the audience was asked to move together. As the show continued, more and more of Itai’s explanations were conducted without dance, or with demonstrations of movements done either by Itai himself or by dancers. These demonstrations with dancers held some of the same characteristics as the first section in which he and Maren danced and he spoke at the same time, but they took on a different character. The movements

were not fully choreographed moments, but rather demonstrative gestures. The moments when “dance was in the driver’s seat” were also different in nature from the first section. In the moments characterized as dance, the gestures used in demonstrations during the science portion were woven into fully developed choreography. I do not mean to overstate this evolution. The elements of choreographed moments, lecture, and demonstrations were components of the first section, but in that section, there was a genuine attempt to blend them seamlessly into a new form, whereas throughout the rest of the performance, we were engaged in creating balance between them.

### **Negotiation**

In the third section of the performance, Maren had what might be called a duet with video. The moving image was a three dimensional rendering of one of Itai’s fruit flies in flight, captured at thousands of frames per second, so that it looked as if the movement was happening in slow motion (see Figure 3 for a still image of the video; the raw footage used for the video that played during Maren’s dance can be seen at <https://cohengroup.lassp.cornell.edu/media.php?show=15>). Late in the process, just before the final Light in Winter performance, we were building the multimedia elements of the show, we carefully crafted and edited the movie to her aesthetic values, so there were points when we reversed the film so that the fly moved backwards.

There were two things about the creation of this part of the performance that were of interest. The first was that Itai loved the edited film we’d made for the dance, even the time reversal, but he wanted to find a way to explain the new movements of the fly to the audience, lest they get confused about the physics involved. The second was that he wanted to show a movie of the fly



***FIGURE 3: A still image of the video playing during Maren’s solo. The three dimensional composite of the fruit fly was created by combining the three two-dimensional images. The two-dimensional images were of the same fruit fly taken at three different angles.***

before Maren’s dance so he could explain how the fly used its wings. Maren wanted the dramatic effect of seeing the fly for the first time as she began her dance. We went around in circles with this discussion for sometime, trying to understand Itai’s point of view. He suggested the audience “wouldn’t understand” or “wouldn’t get it”; however, when he was able to explain what he meant, it was not that the audience lacked the requisite intelligence or that the concept was too complex, it was simply that in science, you do not tell, you show. To him, the audience could not and should not be asked to believe something without evidence. This was a simple fact of science for him, and it seemed to be at the heart of his desire to demonstrate the concepts he was trying to explain. It was true that in most of the show, he was demonstrating concepts either before or during his explanations of them. In the end, Maren and Itai negotiated a compromise in which Itai would show a different, lower fidelity, fly video as he explained, saving the more polished

film for Maren's dance (See Figure 4). This conversation was frustrating for all of us because this was the first time we were acutely aware that we were unable to make a decision regarding the show without compromise. While we successfully negotiated the way the show would unfold, the desire to create an aesthetic experience with movement was pitted against explaining the scientific concept of movement. Maren's belief that revealing the video too soon would impact the visual effect of her dance with the video was as strong as Itai's belief that he could not explain the movement without the visual aid of the film.



***FIGURE 4: The three initial images used to create the composite. This video was shown during Itai's explanation of the fruit fly's movements, prior to Maren's dance.***

I tended to side with Maren, and found myself at a loss to understand Itai's claims that the audience would not understand what he was saying without the film. It was not until Itai said that science shows, it does not tell, that I began to understand it was not that he thought the audience was incapable of comprehending his explanation, but rather, that to simply describe this phenomena would be to violate the norms of science as he understood them. Evidence was required. When presenting evidence to the public, or to students, it often took the form of demonstrating the concept being described. Though I understood his position, and we found a compromise, it still seemed to me that this choice was ideological, and that the opportunity to



create a striking visual moment was slightly diminished by the compromise. At the same time, I might have questioned Maren's assertion that the element of surprise was necessary; however this aesthetic choice seemed to me to be sound based on my past experiences as a producer and designer for theatre. Still, Maren's beliefs about the importance of the moment the audience is introduced to the imagery may have been as much a product of ideology as Itai's need for demonstration.

This process of negotiation was the culmination of a pulling apart of ideas. The first impulse for this creative team was to attempt to build an integrated performance, in which the scenes in the show were not designated as art or science, but simultaneously possessed the qualities of both. But it was not only about integration in the final product, these early talks about integration featured an integrated process, in which discussions would span dance and science. This was the expectation because of Maren and Itai's previous collaboration, which was a much shorter process, and a much shorter performance. Soon, we realized that much of the conversation happened around ways that Maren could interpret Itai's concepts through movement, and talk of the need for fairness arose, first from Itai, and later from Maren. These discussions were aimed at ensuring that the process itself was fair. If Maren's homework was to interpret Itai's videos, what was Itai's? Still later, a fair process gave way to a desire for equal time on stage, as the team's focus shifted again, and we sought balance. Finally, while working to develop a balanced show, differences of opinion arose due to differentiation in the aims for sections dominated by science and those dominated by dance. The result was a need, for the first time, for negotiation to arrive at a compromise between the value Itai placed on providing evidence during explanations and the value Maren placed on creating a visually impactful moment of dance.

## **Demonstration, Explanation, and Expression**

As I analyzed our interactions over the course of the creative process, I wondered why we had arrived at a need for fairness or balance, and why we found ourselves negotiating the performance. The original hope had been for ideas to drive the creation of the show. We had imagined these ideas wouldn't be purely scientific or artistic, but would be born out of some sort of integration of the two. Our idealistic visions of the creative process gave way to fairness, balance, and negotiation because there was a fundamental difference in what Maren and Itai aimed to do: she wanted to express something; he wanted to explain. Maren's goal was to create an expression that would spark a response (usually an emotional response) from the audience. Itai's goal was to explain and thus to generate understanding in the audience. The tension surrounded the difference between these forms of expression and explanation as much as it did their ownership of the moments of the show. They couldn't share ownership of moments because in any given moment, what Itai wanted to explain seemed to take something away from Maren's expressions, and her expression seemed incomplete without an accompanying explanation. The discussion surrounding the video of the fly perfectly illustrates how expression and explanation often seemed mutually exclusive, and, as I reflect on this chapter I am left to wonder if that is inherent in art/science collaborations or if there are ways in which expression and explanation can work in harmony.

Itai's preferred method of explanation included demonstration. This had its roots in Itai's training as a scientist: you teach and learn through demonstration. Demonstration is a time-honored tradition in science classrooms in high schools and at universities, and Itai's respect for

demonstration as a way to share scientific knowledge was based in that tradition. No doubt he was a student observing many demonstrations, and perhaps they were part of the reason he chose to pursue science in the first place. However, research has indicated that these kinds of demonstrations do not necessarily enhance understanding. Some studies suggest that the value of demonstrations is a bit more complex. Crouch (2004) shows that while observed demonstrations may capture attention or interest, without participatory activities like prediction or discussion, they do little to enhance understanding. In the case of *Dance of Scales*, enhancing understanding was part of Itai's need to include demonstration, but he was also interested in capturing attention or interest. In addition, as I suggested above, the ritual and social aspects of science demanded demonstration not only as teaching aid, but also as a method of showing clear and compelling evidence. They were a way to foster trust in science. Explanation and demonstration were part of the performance to facilitate understanding, but they also served the purpose of fostering trust in the system that created the knowledge.

I do not believe aesthetics were unimportant to Itai; visual beauty was extremely important, and on several occasions after this project he discussed the value of moments of reveal like the one Maren imagined when the fruit fly appeared on the screen. But to him, there was a ritual and ideological reason that transcended the need or desire to create such a moment. I think part of the reason this moment was so significant, and so unexpected, for us, was that Itai had championed Maren's requests for freedom to express herself, and had argued early on for fairness and balance in the performance. To me, this was the first time the four of us had arrived at an impasse. There would be no way to work together to sort out the problem without negotiating a compromise.

There was something irreconcilable about the way Maren wanted to express herself and the way Itai needed to explain the concepts.

The expression Maren sought through dance called for movement, but that movement did not need to be coupled with meaning that could be explained in words, nor did the audience's interpretation of that movement have to match her own or one another's. Expression created experiences. The difference between explanation and expression for Maren was the idea of mystery. She believed things should be left to the audience to interpret or the audience should simply experience the dance that was happening in front of them. The tensions that were evident in the process of negotiation stemmed from this underlying difference in the idea of what one does for an audience. To me, it seemed that dimensions of expression and explanation should be able to complement one another.

### **Explanation and Expression: Audience Perspectives**

I endeavored to elicit some information from audiences about their experience at *Dance of Scales*, but the data garnered from these attempts were limited. I asked audience members to fill out brief surveys after the performance, and asked them if they could be contacted with further questions. Sixty-three people filled out surveys, and, and thirty-one agreed to be contacted. From the group of thirty-one, I began recruiting audience members for semi-structured interviews. I conducted eleven such interviews.<sup>14</sup> These interviews spanned the final two weeks of March (approximately six weeks after the performance at Light in Winter), so the show was not fresh in the interviewees' minds. During the interviews, I used surveys as well as photographs from the

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<sup>14</sup> One of these interviews was with a Light in Winter festival producer who had been in the audience, and another was with a musician who played the drums briefly during the performance and attended several rehearsals.

performance to refresh memories. When I asked the audience members I interviewed what they liked or what they remembered about the performance, many described it in a way that suggested that they might think it to be either integrated or balanced, but these definitions seemed more like fluid observations rather than concrete assessments. After all, the audience wasn't aware of the process, nor were they asked to think through such specific definitions of how the process or product of *Dance of Scales* combined science and art. Audience member 1 used the word fusion, which I would liken to integration, along with the word balance to describe the relationship between art and science, and audience members 2 and 3 seemed to indicate they thought the performance was integrated in some way.

AUDIENCE MEMBER 1: There was a real fusion and that the two aspects were quite well balanced...I was equally drawn to both...it seemed to me that it shifted back and forth between one focus and the other, there was enough connection that it did—like—the word *fusion* came to mind.

AUDIENCE MEMBER 2: I think it was trying more than many performances to do the integration...My least favorite type of Light in Winter performances are ones in which the scientist speaks first and the artist goes second. It's like, "bam! uh... err... Link those two!"

AUDIENCE MEMBER 3: It was a nearly seamless weaving together of scientific ideas and an artistic reaction to them. So it wasn't just dance in service of science, and it wasn't science in service of dance, but it seemed like a very strong collaborative effort.

I asked one audience member if he thought the show was balanced, and I want to note that this is a situation in which my role as a practitioner impacted my research. Had I taken a step back to

analyze, I might not have used the word balance. Instead, I had been focused on balance because that was the primary word used in most of our later conversations about the shape of the performance. Interestingly, the audience member picked up on the differences between balance and integration, and had his own opinion about what he had seen:

AUDIENCE MEMBER 4: Balance is an interesting term to describe it because I would almost say that synthesis would be what I would perceive to be a goal. Or integration as opposed to balance. Because you achieve balance by doing half dance and half you know, lecture right? And so that's an interesting choice of terms and I guess I would not think of it in those terms. That said, in order to achieve integration and synthesis, for lack of a better term, you need some level of balance I guess. It would be hard to put two things together if one completely outweighs the other, right? I don't know, somehow balance doesn't seem quite right to me.

However, when asked how they would describe the performance, the idea of integration, while not completely abandoned, was replaced with descriptions of different kinds of reaction. Many audience members had a hard time resisting the impulse to choose: a performance with some science in it or a lecture with some performative elements.

AUDIENCE MEMBER 5: [It was] a very interesting lecture with artistic elements.

AUDIENCE MEMBER 6: I would say it's a multimedia performance that combines some talks about some current ideas in physics research and combines those with some creative modern dance, along with some video and music. So it's this combination of a lot of disparate media that are all brought together and

interwoven, so you end up interweaving science, modern dance, video, music to make a performance out of it.

One audience member noted that the piece was a much more nuanced combination of dance and science than he had anticipated. This same audience member used the term fusion earlier in our conversation, but maintained the separate nature of the science and dance. Here, he also maintains that the two were separate, but articulates that the lecture was a kind of performance as well, and that the two aspects worked well together.

AUDIENCE MEMBER 1: I think maybe my expectation going into it was that it would be more, maybe, more of a dance piece [...] I wasn't expecting Itai to take such an active role in performing, or for, you know, for the lecture to become a performance [...] felt like the dance made room—the choreography— made room for the explanation really graciously.

Still others noted that the dance consisted of metaphors that helped the audience understand the scientific concepts. Though many audience members described the performance as integrated, they often described two differing ways of receiving the show, or any given moment in the show, as an expression or an explanation. Some audience members said they could both understand the science and interpret the dance, but none reported doing both simultaneously. Some people watched a dance piece that was inspired by science, some watched an augmented lecture, and still others were unable to say which element was the primary focus. The dual goals of explanation and expression were met with the dual responses of understanding and interpreting, and clearly, audiences had the opportunity to do both during the performance if they wanted to; however, at any given moment, one seemed to be winning out. These choices harken back to

Elkins (2008) and Ede's (2002) assertions that in most interactions between art and science, one was put in service of the other. Though audiences were able to recall that they were learning about, and understanding, scientific concepts, few, if any audience members remembered specific concepts clearly. Instead, most recalled emotions, imagery, moments, activities, and some would recall enjoying or understanding specific concepts, but they were not able to recreate the information or demonstrate recalling Itai's explanations.

Though there is much similarity in these answers, and they all point toward the ways audiences were quite perceptive about the aims of the piece as well as the realities of the process. I don't find one particularly compelling account emerging from these interviews. Rather, I see fragmented understandings and interpretations of the roles of art and science, the way they were combined, and whether it was dance or science "in the driver's seat."

### **Demonstration, Expression, and Audience Participation**

Maren and Itai seemed to find some kind of harmony between expression and explanation during the small section of the performance that featured audience participation. Before I explain the participatory aspect of the show, a bit of background regarding audience participation is necessary. During their first collaboration, Itai and Maren had hoped to involve the audience in their performance, but had not been able to incorporate audience participation into the final product. I used the first meeting between us for this project as an opportunity to ask about their views on why they had not been able to incorporate participation, and why they had wanted to do so.



MAREN: I think what we focused on instead [of audience participation] was making-presenting the performance in such a way that they would feel involved, like, by the way that we stood and the way that we talked with each other and the way that it wasn't just us telling them something but we were having a conversation that we invited them to join us on. So we kind of shifted to that that since—, like making sure they were with us even though they weren't actually doing something with us...

MAREN: I think it takes a lot to make the audience understand what they need to do. And I don't know that the kazoo thing worked in the end. So I'm interested in it, and I have a dream and a vision [Maren describes in detail a scene from the movie *Mama Mia* in which a large group of people sit on a doc wearing flippers and moving in unison]. The point is its really great to see so many people doing something simple together and so I have a vision of somehow just motivating a big group of people to do something together. And so that's what I was thinking, when we go to Berkley, maybe there's a part of that that I can just you know you teach the rules and you teach what to do and somehow— don't know how that happens I've never done it before, but I think it's really powerful.

ITAI: I have seen people who are dancing or um, singing, interact. I mean, man, if you can get the audience to be on their feet and start moving, then there's something there that is a connection, and it really does make a different performance. But I haven't seen much other things where the audience becomes, really [trails off]. So I'm starting to think whether or not that's necessary. There are other things like, if you're doing a question answer session or if you're feeding off the audience questions—sometimes when you go to a really good conference or a really good talk people will be screaming out things “well what about this” and they'd say, “No! Because blah blah blah blah!” And there's like a whole dynamic that's set up, and its usually when a room is so overcrowded and everyone's just like it's hot, and everyone's excited. Or comedy when the whole

audience makes the film because everyone's laughing together and that makes you laugh you don't know why you're laughing you're just laughing cause everyone's laughing, it just feeds off itself.

MAREN: I think you don't necessarily need it. If the performance is powerful enough, then the audience comes away with an experience, and that in itself is beautiful and important and transformative. I've seen that before. I see a dance performance and I'm so moved that you know I don't ever forget it. There's something really powerful about taking pedestrians, like non-dancer just people, and getting them to move together and connect, basically.

Maren found something joyous in large groups of people moving at once. In that moment, the expression she sought was simply that expression of joy at human bodies in motion, together. This nonverbal communication was complete, and needed no explanation or collaborative reflection. Whereas Itai saw the potential for what he called "creating a connection" when he began to develop the participatory aspect of the show, he found it was an interesting and potentially compelling way of using human bodies in motion to help him demonstrate physical concepts for both understanding and for maintaining the epistemic authority of science.

We developed a small interactive section in the performance that met Maren's desire to see a large group of people to move together while at the same time helping to illustrate a property of movement on the nano scale. Itai explained that most of the time, when you are taught about entropy in high school, you learn about entropy as the degree of disorder in space; however, on the nanoscale, entropy actually leads to order rather than disorder. To demonstrate this so the audience could understand through embodying the phenomena, we created a simple movement that most people could manage: audience members were to raise one arm above their head, in an

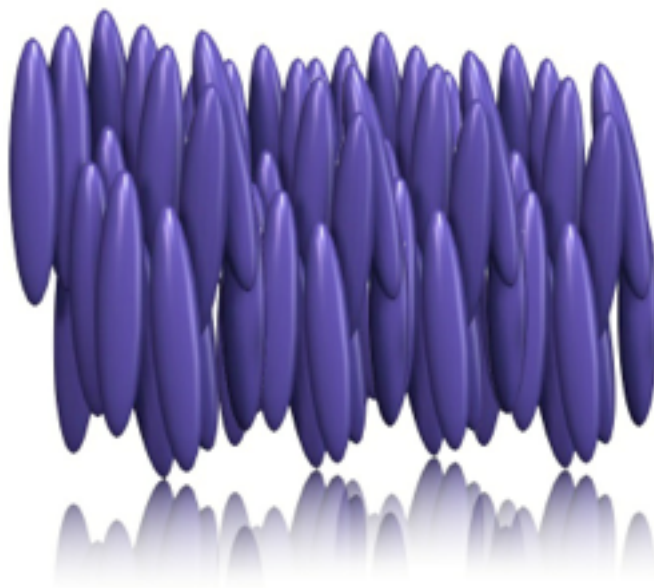


***FIGURE 5: The interactive experience during the performance in California. Audience members begin to move closer together while continuing the flowing movement of switching their arms.***

arc, with their palm facing down while lowering the other, also in an arc, with the palm facing up. In a flowing motion, they would slowly switch their arms back and forth (See Figure 5).

They were to continue this movement for some time. They were supposed to spread out and begin this movement, and then, while continuing, come closer and closer together. Once they were close enough, they found they would hit one another unless they aligned themselves so they were turned diagonally. In order to explain this, Itai made use of images like Figure Y, but it was only when we developed the participatory experiences that we felt we had a real way of illustrating the phenomenon.

During the performance, Itai and Maren asked the audience to participate in the exercise before explaining to phenomenon to them. Once they had finished, he described their activity to them using the image in Figure 6.



***FIGURE 6: The image Itai used as he described entropy. The image was used to help audiences visualize their own positions as they ordered themselves to create greater freedom of movement.***

ITAI: Usually in high school we learn that entropy is the amount of disorder in a system. But entropy simply corresponds to how much space you have to move around in, and how many different ways you can configure yourself. When you have a large amount of space to move around in, it makes no difference what orientation you have relative to your nearest neighbors so you orient randomly and increase your disorder.

When you are all squeezed together very tight however, it turns out that increasing your entropy means ordering. Since the ordered configurations correspond to the most amount of space for moving around.

The fact that entropy causes confined particles to order actually had a lot of scientists confused about nano-particles for a long time. Figuring this out allowed us to understand how oblong particles like the ones on the screen (see images on screen) are made to order in different orientations. By manipulating these orientations we can form regions of different color, like the ones you see here, which allow us to manufacture LCD screens in your laptops and TV's.

This movement you just did, where the group of you started ordering in a particular direction, that's exactly how nano-particles cluster into ordered regions that become big enough to grow.

Shortly before we performed this piece of the show in California, we held an open rehearsal in Ithaca and invited friends and family so we could test out the participatory experience. I was feeling a bit skeptical about if and how audience members would organize themselves. This test run proved that as soon as audience members got close enough that they might bump into one another they organized themselves, as Itai predicted, without much thought or discussion. Itai had hoped, at the time, to have some sort of camera so that the audience could see how they had assembled, but technical and budgetary constraints had prevented us from pursuing the idea. Once I saw that audiences would react in the way we had hoped, I was convinced that embodiment of the phenomenon was enough, and that audiences did not need to see themselves from afar to understand that they had organized themselves.

Though this was still largely a way to illustrate science through movement, a demonstration, or showing of something Itai wanted to tell, it was also an expression of something, at least to Maren. Her hope of getting a large group of people to move together had been achieved. This is not to say that that moment was fair or balanced in the ways that Maren and Itai had spoken about the aim of balancing their needs. Clearly the explanatory dimension of the activity drove the choices they made for the audience. But, the “unfairness” or “imbalance” was not a problem in this particular instance because there was something there for Maren to grapple with: the choices she made about the audience choreography. The movements had to be easy enough for most audience members to feel comfortable attempting them; they had to be disruptive when

audience members got close enough to one another; and they should incorporate Maren's aesthetic and dance style. The easy movement was flowing and beautiful enough when it was done alone, but when audience members got close enough and oriented themselves, which they usually did, the unified movement was visually powerful to those of us observing the movement. When I participated, I felt something somewhat different. I felt there was beauty in the feeling of completing the motions Maren had created for us, and in doing so with others.

I asked audience members specifically about the participatory experience, and whether or not they could remember the specific concept or the language used to describe it. Almost all of the interviewees clearly remembered the movement. Specifically, they all remembered moving their arms and most remembered that if they turned sideways, they could continue to move their arms when in close proximity.

AUDIENCE MEMBER B: Yeah I guess the continuity from one to another was really nice and I guess I wasn't expecting to do an audience participation component when that happened and then we were doing it and it was neat and sort of illustrative and then I guess you might describe it as "mood" in the way that these things work together to create different moods at different times really worked well.

## **Conclusions**

Because the show was created in chronological order, the pulling apart of art and science became encoded into the performance, forming a subtextual story-line. The first section, movement at the nanoscale, featured Maren and Itai moving together on the stage. Itai was dancing with Maren as he spoke, and some of the illustrative movements she created to explain his work seemed to be

somewhat choreographed moments of their own. As the performance progressed to larger scales, each was a bit more polarized, as if you could see the stages of integration, fairness, balance, and negotiation play out on stage, until the end, when Maren danced with the other dancers while Itai stood aside. The process of negotiation became encoded into the performance itself, as well as the transformation from the initial form of collaboration to negotiated form. The result was that in each section of the show, the dance and science became increasingly separated. In the first section of the show, Maren was dancing with Itai throughout. They were communicating with each other on stage as much as they were with an audience, but as the show progressed, Maren was interacting more with the other dancers. At one point toward the end, the lighting even changed so that Maren was in light and Itai was in darkness while she danced, and then the lights went down on her, leaving much of the stage in blackness as a small spotlight came up, lighting Itai while he spoke and then disappearing as the rest of the lights came up on Maren again.

My reflections on this experience have left me to wonder if the differences between Maren and Itai ran deeper than differences of this particular team or this particular project. I wondered if the difference between expression and explanation was something I saw just because of the contingencies of this particular experience and the people involved, or if the two were, in fact, mutually exclusive. Does explaining a scientific concept always explain away the opportunity for creative expression?

A deeper discussion of the concepts of expression and explanation is warranted, because the two are intertwined, and the distinction I describe above is my interpretation of Maren and Itai's perspectives on expression and explanation, rather than my own understanding of the concepts.

That is not to say these were actors' categories, but rather, categories created from my interpretation of actors' choices. My own perspective differs from my perception of theirs, and can shed some light on the complexities of how they made sense of expression and explanation to help them create the performance. An expression, in this case, reflects or suggests meanings, but remains open to interpretation, while explanation establishes fixed meanings. But constructivist approaches to knowledge might suggest that representations of meaning need not be something separate from creating meanings; therefore, there is a sense in which these are not separate activities, but rather, explanation is a particularly constrained aspect of expression. When one seeks to express something in the form of an explanation, they are still seeking to represent meaning in some way, but rather than being open to broad interpretations, they may see their explanation as possessing a kind of rigidity. Explanations, then, do not seem to be open for interpretation with the same kind of freedom as expressions.

This expression/explanation tension is reminiscent of arguments brought up during the science wars: part of Sokal and other scientists' problems with cultural studies was the idea that scientific knowledge was in some radical way open to interpretation, rather than a reasoned and fixed view of reality. The tension manifested itself in a much more collegial way in this case largely because in the case of *Dance of Scales*, unencumbered expression and expression constrained as explanation could exist side-by-side, even if they were not integrated. Perhaps the constructive boundary work that allowed Maren and Itai to collaborate also allowed expression and explanation to inhabit separate spaces and thus, to become separate entities where they might just as easily vied for occupation of the same space, as they did during the science wars. In other words, perhaps the only reason Itai and Maren could successfully collaborate at all was because



they had abandoned integration in an attempt to build a balanced performance. Their related but separate sections of the performance did not encroach upon one another's territory. Though Itai's sections included movement and aesthetic choices, and Maren's movements were inspired by Itai's explanations of his work, they each occupied a separate space. As Ede (2002) and Elkins (2008) suggested, either art was in service of science, or science was in service of art throughout the piece, and the overall piece itself seemed to be rooted in art as a way of illustrating or demonstrating science.

This led the creative team to be concerned that the imbalance between art and science always tipped toward science; however, in the end, expression may have won the audience. One benefit of interviewing audience members when the performance was no longer fresh in their minds is that we got a sense of what they remembered, and what they found important. From the small sample of interviews, it would appear that movement, visual imagery, and experiences were recalled, and scientific details were largely (but not completely) forgotten. It also seemed to me that there was a sense that the scientific information was valued, but that it was valued as part of the experience of witnessing, or taking part, in the demonstrations, rather than as an explanation of a specific concept. What audience members described when they recalled the performance was the sense of integration or balance, the way they felt about the interactions and the demonstrations, the overall feel of the dance.

The less constrained form of expression seemed to be more compelling to audiences, or at least more apparent when they recalled the experience of seeing *Dance of Scales*, which might have implications for public engagement with science. Constrained expression, or explanation, is

likely what most science communicators were attempting when working toward science literacy (which we now view as the deficit model) or the public understanding models. Indeed, this is still what most scientists unfamiliar with the scholarly literature on science communication are still working toward. It is certainly what Itai was attempting. However, engagement is not similar to the kind of expression Maren was attempting. In a sense then, even engagement, the model of science communication predicated on democratic principles and aimed at leveling an uneven playing field, seem to foster explanation, or constrained expression. This aligns with Peters' (1999) critique of dialogue as a potentially oppressive need for two minds to come to the same meaning.

Peters' discussion of dissemination and dialogue contradicts the current interpretations offered in science communication, but might be helpful in understanding what was happening in this case. Where science communication experts might suggest that the one-sided nature of dissemination is oppressive, Peters suggests it is freeing. He likens dissemination to sewing seeds: some grow; others don't; each grows in its own way. Alternately, he says dialogue is a format in which meaning seeks to replicate itself in the mind of the beholder. Such a reversal might seem counterintuitive, but one need only look at Maren and Itai's different approaches to expression and explanation to see Peters' version of dissemination as open expression, in opposition to dialogue, which more closely resembles explanation. Maren wanted to create something that could be observed and freely interpreted, while Itai wanted to create something that had a single interpretation. This position is much more akin to the way Peters describes Socrates' version of dialogue and public speech. "Even in public address, Socrates proposes close correlation between speech and the audience; the careful crafting of discourse can approximate the intimacy

of dialogue on a large scale” (p. 50). On the other hand, Maren’s expression might be the most open form of dissemination. She asks audiences to freely interpret and make their own meaning. If explanation is one side of a dialogue, wherein Itai tries to share the specific ideas in his own mind and match them to the audience’s, then expression, in this case, is Maren’s hope of creating something for audiences to turn over in their minds and make their own. She even suggests that some dance need not have a specific intended meaning.

## CHAPTER 5: *EMERGENCE*

After *Dance of Scales*, there was much discussion of what next steps might look like, and whether the show should continue development. Instead of refining and remounting a production of *Dance of Scales*, Itai decided he would like to try another kind of performance, a play, as a vehicle for communicating his research to wider publics. He had had several conversations with Melanie, a director and a professor in the Performing Arts department, and she was interested in collaborating with him on a project. The result of this two-year collaboration, which was much larger than *Dance of Scales* in scope, ambition, and size of the collaborative team, was *Emergence*, a one-hour, interactive performance (See Table 1 for a timeline of development activities). In 2010, Itai, Max, Melanie, a director and theatre professor, and I set out to create a performance based on Itai's work. Though the project evolved and changed drastically over time, and a new collaborator, Aoise, a playwright, joined our team, the central focus of performing Itai's research and his interests remained constant. The group easily awarded epistemic authority to science early in the process, often characterizing their work as a way of explaining or generating interest for Itai's research.

Just as in *Dance of Scales*, there was a tension between different ways of interacting, though the tensions were aligned differently. Once again, the collaborative team worked diligently to integrate their differing perspectives on what to do with and for the audience. The process of creating *Emergence* was more complex, in part because of the greater number of collaborators, and in part because of the introduction of interactivity as a major component of the performance. The result was that it did not follow the same trajectory of integration, fairness, balance, and negotiation that drove *Dance of Scales* toward its final incarnation, but there were some

<b>Dates</b>	<b>Nature of Activities</b>	<b>Collaborative/Production Team involved</b>
Dec 2010-Jan 2011	Initial meeting and two boundary probe activities	Itai, Melanie, Max, Megan
Feb - Dec 2011	Team meets monthly to discuss ideas and structure the performance.	Itai, Melanie, Max, Megan
Jan - Feb 2012	Playwright joins the team. Weekly meetings in which different collaborators design probes for each section of the performance.	Itai, Melanie, Max, Megan, Aoise
March - April 2012	Script development through boundary probes; tour of Itai's lab	Itai, Melanie, Max, Megan, Aoise
May 2012	Auditions held, cast is chosen	Itai, Melanie, Max, Megan, Aoise, 5 actors
June - July 2012	Production meetings begin, designers tour Itai's lab, Itai and Aoise write together	Itai, Melanie, Max, Megan, Aoise, 10 person production team
Aug - Sept 2012	Rehearsals begin, script is revised during rehearsals. Performances are at the end of September.	Itai, Melanie, Max, Megan, Aoise, 5 person cast, 3 person crew, design and 10 person production team
Sept 27, 2012	Postmortem Dinner with creators of the show	Itai, Melanie, Max, Megan, Aoise

***TABLE 1: A timeline of Emergence development activities***

similarities, including a hope for something that might be called integration and a process of negotiation. Again, there were tensions between what might be called expression and what might be called explanation, but these did not break down along the art/science divide, nor did expression look the same in this medium as it did in dance. Whereas Maren made it clear that in dance, there did not need to be a clear, established meaning, many theatrical productions do involve such a meaning. Just as science must be explained, plot lines must follow a trajectory that seems natural and real, and an agreed upon meaning is often presented. In this case,

completely unconstrained expression, which is what Maren seemed to be developing with her dance, was not present. In other words, as Hall (2000) suggests, a preferred reading is encoded into the text.

While I did not see the same kind of discussions about fairness or balance I witnessed in *Dance of Scales*, the process of negotiation was similar. There were times when the meaning of the scientific explanations and the meaning of the story itself were at odds with one another, and negotiation was required to make decisions about plot and dialogue. These instances were reminiscent of the negotiation between Maren and Itai in *Dance of Scales*, despite the difference between Maren's idea of expression and the kind of expression I might characterize as a plot. In addition to negotiations over explanation of science and plot development, negotiation about how to handle the participatory moments was also necessary, causing a different kind of tension. We were navigating narrative meaning, explanations of science, and participatory moments that required explanation of science but also of simple rules for participation. And these moments, while breaking from the narrative, had to sit comfortably within it.

The use of the participatory moments had several motivations. There was a desire to build the performance around interactive experiences with scientific knowledge; a desire to invite new and experimental forms in theatre; and a desire to embrace feminist theatre (and to some extent, feminist ideologies in science studies as well). In light of the competing agendas behind the use of experimental theatrical forms, I will look at the negotiation of how and when this experimentalism was used as a kind of boundary work, and the concept of audience participation as a troubling boundary object through which the boundary work was conducted. These varying

concepts of audience participation and interactivity ended up in competition with various understandings of narrative theatre such that the boundary objects of audience participation and narrative became the territory for which the collaborators would attempt to establish authority, but not necessarily epistemic authority, which already fell squarely on the shoulders of the scientist involved in the project. Instead, I believe there was a different kind of authority for which various forms of participation and narrative vied.

### **The Making of *Emergence***

#### **Early Development**

“When Megan brings her pens, we know it’s time to play.”

The project began with four of us, each with our own reasons for participating and our own agendas when it came to what we wanted to create. Itai sought another performative way to present his research; he expressed a desire to inspire young physicists to consider solid state physics, or materials sciences. He also hoped for a way to make his work as appealing to the general public as “sexy” topics like cosmology and quantum theory. Melanie was interested in new collaborations, and more broadly, in interdisciplinary work within the university as a way of showcasing the relevance of theatre in the university setting. She was also known for creating more experimental than traditional theatre. Melanie and Itai approached Max and me to act as collaborators and facilitators. Max, an informal science learning practitioner and theatrical producer, sought an opportunity to co-create and produce a performance that integrated science and art, and to approach the process as a way of creating science outreach. I was also invested in participating in the collaboration between art and science, and in further researching the



**FIGURE 7:** Itai and Melanie in the black box theatre during a probe activity. **FIGURE 8:** Itai, Melanie, and Max during a probe activity in Itai's laboratory. Photos taken by Megan Halpern.

collaborative process as well as the audience reception of art/science collaborations. This time, my role as a researcher was clear from the outset of the project, and I was eager to embrace my dual role.

From the beginning, I envisioned *Emergence* as a probe-centered collaboration. In 2010, when the team first met to clarify everyone's goals for the project, I offered to create a boundary probe<sup>15</sup> for the team to help us develop an understanding of one another's perspectives and to

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<sup>15</sup> At the time, I still called them cultural probes, after Gaver's original concept (1999).



develop a vision for the future of the project. This first conversation had turned to space and place, prompting Melanie to suggest we hold two separate events; one in Itai's lab and another in the black box theatre<sup>16</sup> at the Performing Arts Center. Situating these events physically in these two spaces would help the collaborators familiarize themselves with one another's realities, but at the same time, these encounters seemed to showcase the collaborator as observer, or 'other', in unfamiliar territory. The meetings explored several abstract concepts, like familiar versus unfamiliar, perspective and scale, and engagement with the physical space. For example, the person visiting the space was asked to choose an object they found interesting and speculate about its use, then the "host" was asked to identify their favorite and least favorite aspects of the space and discuss why they'd chosen these aspects. The pair was then asked to work together to draw maps of the space, to build stories around the space, and to identify common properties of the two spaces. The probe from Melanie's theatre contained the following prompts:

Itai: You are new to this space. Please choose the most interesting thing in this space. Why is it so interesting? What purpose do you think it serves?

Melanie: You are the host today. What is your favorite thing about the space? Why is it your favorite thing? What is your least favorite thing? Why is it your least favorite?

Together: What does Melanie's favorite thing have in common with the object Itai chose? How are they different?

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<sup>16</sup> A black box theatre is a common type of theatre for small productions, and is named for its appearance. The value of a black box space is in its flexibility: it can be used as a traditional space in which the audience is on one side and the stage is on the other, or it can be used for theatre in the round (audience is on all four sides and the stage is in the middle) or arena theatre. Black boxes are often used as rehearsal spaces for larger shows on main stages.

Itai: Choose something in this room that relates to your research. Tell a story about how it is related to your work.

Melanie: Build on Itai's story. Incorporate something else from the room.

Together: Draw something you would like to add to the space. How would you use it? Draw a map of the space in terms of theatre and physics.

The probe at Itai's lab was a mirror image, reversing Melanie and Itai's prompts.

At the end of the second probe, the four of us adjourned to Itai's office, where we spent about twenty minutes reflecting and discussing future directions. The conversation repeatedly turned to audience participation and what might happen when spectators were asked to be part of the performance space in some way. Melanie and Itai both had thoughts and ideas about creating participatory experiences, but Itai was reluctant to part with the idea of a narrative story, citing his past experiences as an audience member with interactions that lacked narrative as underwhelming. For Itai, participation could be an exciting, valuable addition to the process, but it could not replace the emotional connection of character and narrative. He therefore advocated for the use of both participation and narrative.

It also became clear that Melanie and Itai had different ideas about how to incorporate or think about participation. Itai's ideas about participation were similar to his ideas during *Dance of Scales*: they were deeply tied to his commitment to demonstration as both a tool to communicate and as a commitment to his scientific principles. As such, he was quite interested in continuing and expanding the same kind of participatory experience he and Maren developed for *Dance of Scales*. Melanie's prior commitment to experimental theatre and her desire to break with

conventions likely drove her excitement at the thought of creating participatory experiences.

Melanie began to talk about the kind of participation she wanted to see as a form of experimentation with unfamiliar relationships between the audience and the performers. For Itai, however, the participation would help demonstrate specific scientific phenomena, so audiences would have to follow specific rules that mirrored the behaviors of the phenomena he wanted to show.

MELANIE: I love the idea, if I can leap to this already, in terms of the event itself, of rearranging the audience's relationship to the performers. This box has existed in both, so is there a box we can construct so that the audience is both the witness and the experiment? That interests me a lot.

MEGAN: Could your flies study themselves?

ITAI: No, I mean the flies can't study themselves.

Here, Melanie broached the subject of audience participation. For her it was a way to change the relationship between the audience and the performance. The use of the terms witness and experiment are indications that she had already embraced the language and format of scientific demonstration to some degree (see Shapin & Schaffer, 1985), but her preference was for the audience to somehow study their own behavior. My question about Itai's flies studying themselves was meant to provoke deeper discussion about her aim. Itai continued:

ITAI: I guess that the flies study themselves in the sense that if you clip half their wing and they figure out how to do something different to do the things they want to do

MAX: Make adjustments

[The group engaged in extended banter about animal cruelty and invertebrate animals]

ITAI: Having the flies study themselves, that's a pretty literal thing. But for example, having the neural circuit study itself, that's a pretty weird concept. Um. You know, which is basically what the audience is doing. How would you even study a neural circuit? You know, you could do it on the micro scale, in terms of bringing in this idea of scales. What does it mean to look at just one neuron?

MELANIE: If we created an experience in which the audience enters a space and they are able to construct their own story by behaviors, you know. I'm totally fishing here.

Here, Melanie shifted gears a bit. She adopted the language of theatre again, and asked how the audience could construct the story. Between her first attempt to express this idea and this second attempt, she was grappling with what she wanted for the audience. Here it seems as if she wanted them to have agency, not just in terms of their own interpretation or meaning making processes, but in terms of the performance itself.

ITAI: What about that dance we were talking about.<sup>17</sup> You give them a set of rules, and then you film them, you film the audience. Then you get this kind of emergent behavior of these swirly flows. I told you about these cellular automata, right? That's kind of like these boyds idea.<sup>18</sup> You give people a set of rules, and the rules are: each second you have to step to the next thing. If two people step in, you have to rotate by some amount and go in opposite directions. Once you do that, then you start to film them from above, and they will create the same kind of swirly patterns that you see in a fluid flow.

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<sup>17</sup> I believe Itai is referring to a conversation he had with Melanie before we began the project. He may also be referring to the conversation he had with Maren, Max, and me during *Dance of Scales*. It becomes clear in the next few meetings that Itai has been thinking about this idea for some time.

<sup>18</sup> An idea discussed during the first probe event at the black box theatre.

MELANIE: Is there a way to give them perspective on that event? Let's say they achieve it, their reward is to see it projected on the wall or on the ceiling or, you know, there's some...

Several times during this conversation, Melanie referred to whatever impact the audience may have on the performance as a 'reward' for the audience. I found this to be a really interesting word because it presumed the audience would enjoy impacting the performance in some way, and that enjoyment was to be earned by participating.

ITAI: There's no way for them not to achieve it.

MELANIE: Really?

ITAI: Yes. It just is. You put in the rule and this is what happens.

MELANIE: Really, with people?

ITAI: Yeah. [laughter] It's just the rules. I mean, there's nothing you can do.

MELANIE: People don't always behave. They don't always follow instructions. They're very arbitrary.

ITAI: That's true. If they don't follow the instructions, then you don't know.<sup>19</sup> But within the guidelines they can do whatever they want.

MELANIE: But they have to learn the guidelines, right. They have to—here would have to be a process...

ITAI: Yep. You teach them the rules, they're pretty simple. But I think those are the themes that are playing out in my head. I'm okay with the audience studying

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<sup>19</sup> I believe Itai meant to say that if the audience does not follow the instructions, they will not create the kind of pattern he is hoping to show.

themselves, that's interesting to me. The kinds of things that emerge from simple rules, that's interesting to me. I don't know... [trails off]

Itai and Melanie had very different ideas about what it would mean for an audience to be given a set of rules to follow. Melanie's chide that audiences do not always "behave" or "follow instructions" did not match with Itai's assertion that the rules just exist and because they are there, a specific outcome can reliably be predicted. Itai did not imagine a situation in which the the outcome of performing an experiment with humans given a set of rules did not approximate the results of the actual experiments. He did not seem to consider human error, inability, or lack of desire to follow those rules to be as great as did those of us who had worked in theatre. Melanie's suggestion that the audience might not behave provided insight into the attention audiences need in order to be able to follow the kinds of rules Itai wanted to develop for them.

MELANIE: I like the idea that the crowd has the opportunity to decide what some of the environment is, so that each crowd, each collection of audience members constructs a unique performance, based on whatever choices the members make.

ITAI: Yeah. It's true that whatever swirling pattern they make will be unique.

MELANIE: But maybe that can affect, can be a component of lighting or music. There are ways that either their behaviors or their choices put together a collection of ingredients that impact them.

This conversation was one of the first discussions we had about the specific interactive moment focused on the rules of momentum conservation and how we might get audience members to enact, and thus experience, these rules. By the end of this small exchange it was clear that Melanie's idea of what the audience should do was quite different from Itai's, and that their

different ideas might closely resemble the tension between expression and explanation In *Dance of Scales* Here, though, rather than creating an expression for audiences to freely interpret, Melanie wanted audiences to somehow shape the performance, perhaps even creating their own form of expression about the given topic. Melanie seemed to be thinking of a situation in which they would be able to make conscious decisions that would affect something beyond their own collective behavior, while Itai believed they should follow the rules established by observation and that the resulting phenomena should be observed. Though it was clear that Itai and Melanie had quite different ideas about exactly how much agency the audience should have, they were not discouraged from pursuing participatory experiences for their audiences. Like the video issues in *Dance of Scales*, these differences would ultimately lead to negotiation over how the interactive moments would look. Once again, this was a kind of boundary work in which the role scientific information would have in the experience they were designing was called into question, rather than the epistemic authority of science itself.

As we began to collaboratively envision a highly participatory experience, we discussed what we could realistically expect from an audience, and what was fair to ask of them. Melanie said that she did not want the audience to feel manipulated by asking them to participate, and that we would have to be very careful and selective about what we asked the audience to do. The complexities of developing meaningful participation that is also accessible to audience members intellectually and in terms of their comfort level began to come into focus, even in these early discussions. Melanie's tacit knowledge of audiences seemed to stem from years of creating performances, and her experiences seemed to match my own. I would describe this knowledge of

the behavior of audiences as a wall against which our sometimes overly grand ideas about participation would bump.

In future meetings, Itai would return to his original idea of having audience members become particles moving to specific rules. Later, he described a grid upon which particles could travel, and should they collide, they would follow a specific set of rules for where to go next. He had begun to toy with this idea during *Dance of Scales*, but started to articulate it in earnest now. The team envisioned a grid on the floor of the theatre and imagined the audience traversing this grid according to a set of rules that mimicked the rules of conservation of momentum. Itai had discussed this kind of demonstration during *Dance of Scales*, and brought it with him into his



**FIGURE 9:** Actors walking along the grid following the rules designed by Itai to demonstrate momentum conservation. The actors modeled the movement for audience members and helped them follow Itai's rules as they made their way to their seats. Photo by Andy Gillis.



thinking as we developed *Emergence*. He would also revisit the idea of using a video camera to record and play back the audience's movements so they could see themselves as a group. The grid on the floor and the camera overhead became an early concept of the set design that stayed in our minds throughout the process (See Figure 9). While budgetary and time constraints once again foiled Itai's hope of using a video camera, the grid remained the central visual element of the set design, and the first interactive moment featured audience members following rules to traverse the grid.<sup>20</sup>

For the rest of that year, the four of us met regularly to continue planning the performance, but we also took time to seek funding sources for the project. The bulk of this time was spent on a proposal for an NSF grant in Informal Science Learning called "Connecting Researchers and Public Audiences." The grant writing process and much of the early development of the performance happened concurrently; meetings were often split between time devoted to grants and time devoted to project development, but that did not stop the two from overlapping. The result was that our thinking about the audience and structure of the show were tied strongly to NSF objectives for communicating current research to broad audiences. Though we also developed grant proposals when creating *Dance of Scales*, the grant writing process was not so intimately linked with the creative process, and so the ways the grant impacted our thinking about the project were not as visible to me. I was acutely aware of how our work on this grant shaped our thinking for the eventual performance. In our discussions, Itai often told us that we

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<sup>20</sup> The possibility of taking *Emergence* on the road to a conference or high school came up early in team discussions, and impacted the show's length, cast size, and production values. Though tourability is also attractive for theatre festivals, the fact that conferences were the initial sites considered for possible subsequent performances speaks to the kind of spectator imagined and to the significance of education as a factor in public engagement.

were framing the grant as an informal science learning project, but that we need not think of the show that way as we were creating it. However, once we had written such clearly articulated aims for the performance, it was nearly impossible to toss them aside and think freshly about what kind of project we were doing. We proposed presenting the performance to college students at science conferences. Our stated aim was to “develop a novel experiential learning program in the form of a theatrical play that will communicate research discoveries made by the Cohen lab on emergent phenomena to prospective physics students and public audiences.” Our aim of reaching potential future scientists became such a part of our conversation that, months later, that language would creep back into our conversations. When we spoke about the project, we often said we were doing this, primarily, to showcase Itai’s work, or to entice young scientists to think about materials physics. Broadly, the goal was to communicate science with the intention of fostering appreciation. This was always met with the answer, from all of us, that we were also interested in creating art, and we were interested in an equal partnership between the two. Itai, in fact, was often the first to suggest this.

Over time, the four of us arrived at a basic structure for the show. The play would discuss emergent phenomena at four levels, moving from the microscopic interactions between atoms to the macroscopic movement of flocks of birds and crowds of people. This structure echoed the structure of *Dance of Scales*, but the concepts were focused on slightly different phenomena, and the theme of emergent patterns was, in my mind, much more rich with possibilities for artistic interpretation. There were to be four sections in the performance, each focusing on a different scale, but describing similar phenomena on each scale. Also, for each scale, there would be an interactive moment in which the audience would embody the concepts the actors were

describing, once again becoming part of a demonstration. These interactive moments were to be interspersed throughout the narrative performance.

Our chosen narrative was one in which a female physicist embarked on a kind of high stakes journey that led her into conversations about examples of emergent phenomena at each scale. During one of our meetings, Itai was expressing the need for a highly dramatized journey for the protagonist, and we realized the examples of movement at different length scales could be explicitly tied to the anxiety disorder agoraphobia. For example, we had selected the behavior of neurons as they work together to form thoughts as one of our sections. Such interactions are changed through the use of Selective Serotonin Reuptake Inhibitors (SSRIs), which are often prescribed to treat agoraphobia. Flocking behaviors and the behaviors of crowds were also chosen as potential interactive moments and examples of emergent phenomena. What better way to explore the movement of crowds than through the fear of crowds, a symptom of agoraphobia. We had struggled for some time to come to this narrative structure, and once we had gotten to this point, we felt we were out of our depth in terms of creating a script. Though we had discussed devised theatre, or theatre created through group improvisation, throughout the early stages, we did not imagine the narrative portion of the performance would be devised, but rather, the interactive elements. We collectively decided it was time to approach a playwright to help us develop the script. Melanie suggested Aoise, a playwright and PhD student. Aoise joined our team because the participatory element of the performance and the potential for a strong female protagonist were both appealing to her from a feminist perspective. Much of her work as a playwright and as a scholar was connected to feminist theatre.

## **Writing *Emergence***

The first phase of the writing process, which I would consider a subset of the overall creative process, was a new series of probe activities in which all five of us participated. These focused more on the themes and structure of the play than they did on actual boundary work. First I generated a probe that covered all four sections of the show, and after it was completed, we created weekly probes that addressed, in turn, each of these sections of the show individually. I designed this first probe as a workbook through which the group would move. I wanted us to be able to move quickly through the four sections of the performance, familiarizing Aoise with the concepts, but also making space for visualization and discussion. The aim of the exercise was stated on the first page of the workbook:

**Rationale:** Early in the development process, conversations about scientific themes have a tendency to become one-sided: the scientist will describe or explain the concept and the rest of the room will listen. This is because we all want to understand the phenomena with which we will work. However, past experience, as well as established research on science communication, has shown that it is more productive if we can devise a way for the initial discussion of scientific concepts to be a conversation in which everyone participates and to which everyone contributes.

This rationale displays once again a place where my work as a researcher and as a practitioner overlap. I believe, in this case, allowing the workbook to reveal something about my research (however vague it may have been) helped to open the discussion to what the social sciences have to say about science communication. In previous projects, I had carefully protected the actors from such discussions, thinking they would affect the outcome of the project. Now, I felt myself

actively hoping they would affect the outcome of this project. In fact, later in the process, I described the three paradigms of science communication (the deficit model, the public understanding model, and the public engagement model) to the collaborative team so that they would understand the engagement model. I was surprised that the response to the concept of engagement was negative. Memory is imperfect, but I recall describing first the deficit model, then the idea of public understanding, both of which were met with nods by Itai, Melanie, and Aoise, and then finally I described PES (public engagement with science) as a way of inviting a two way conversation in which scientists learn from the public, at which point, all three of them shook their heads. The resulting discussion was a refrain I am quite familiar with, having heard it from many scientists and from having uttered it myself many times: You cannot have a dialogue about science if one side does not understand the science. But the discussion went beyond this common refrain. It led to a deeper discussion of the value of expert knowledge in both science and in art, and to a clear boundary being drawn between professional and amateur; between expert and audience. Aoise recounted a story in which the author Margaret Atwood was told by a brain surgeon that he'd like to write a novel and replied by saying she'd like to take up brain surgery. The meaning behind this was clear: the specialized knowledge required to be a playwright or author or any kind of professional artist for that matter was on par with the specialized knowledge required to be a scientist. I found this exchange revealing: no matter how much they wanted to invite audience participation, there was still a knowledge gap, and thus, a barrier between the creators of the performance and the observer. Perhaps this barrier can provide insight into the difference between the participatory exercises in which we were engaged and those that we devised for the audience.

<b>Scene:</b> From individual locomotion to flows in crowds
<b>Description:</b> This scene will expose the audience to how scientists are trying to reuse some of the ideas in statistical mechanics to understand how local physical interactions – such as the establishment of personal space – lead to the fluid like flows often characteristic of crowd behaviors and flocks.
<b>Visualize:</b> Flocking birds, the movement of crowds in riots, mosh pits at concerts, schools of fish.
<b>Discuss:</b> Why is this a compelling phenomenon to express?

**TABLE 2:** *Page 2 of the workbook used in the collaborative probe. Page 1 contained directions, and subsequent pages were structured similarly to Table 1, but with variations in descriptions as well as what to visualize and discuss.*

The workbook took us through the same exercise for each of the four sections of the performance. Beginning with the final section, the group was given a brief description of the phenomena they were to consider, some examples to visualize, a topic to discuss, and fifteen minutes to complete their discussion. For example, the first prompt (See Table 2) in the workbook examined the largest length scale<sup>21</sup>, the human scale, and asked the creative team to consider what was compelling about emergent phenomena at this length scale. Max, Melanie, and I took turns developing the subsequent probes (Max and Melanie asked to participate in this way; Itai and Aoise opted not to develop probes themselves). These probes included activities in which the five of us wrote short paragraphs responding to images; enacted particle behaviors by chasing one another through the theatre building; observed pedestrian traffic in a particularly busy intersection of the University campus and the college town; and attempted to keep multiple tennis balls moving in different directions at the same time. Each activity was designed to

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<sup>21</sup> The term “length scale” was Itai’s preferred term for what might be referred to by non-scientists as simply as length.

investigate the theme of the week: particle movement, neural connections, and human interactions. The probe that was devoted to the scene described in Table 2 asked us to examine the movement of strangers on the street. The prompt read:

Go to [a nearby coffee and bagel shop], small pads of paper in hand, and look for three things:

1. Observe people physically adjusting to those around them.
2. Observe an instance when someone didn't adjust. What happened?
3. Observe what made you uncomfortable and what made you comfortable. How did you adjust your own behavior?

Do you have any other observations about the crowd?

We completed these mini ethnographic observations and regrouped to share our findings. We paid attention to how people organized themselves in lines, which way they leaned, what kinds of affordances were provided by the structures of the street and sidewalks (the sidewalk became narrow in certain places, prompting passersby to adjust as they walked past one another). There was no direct correlation between these moments and revelations about the script or the show, but they added to our collaborative understanding of the movement of crowds and provided participatory experiences for us as we attempted to develop participatory experiences for the audience.

After we completed the five probe events, Aoise began to write a script drawing on the fruits of this collaborative work, but within the limits of the partially developed narrative we had given her when she joined our team. There were, in a sense, a set of rules in existence for Aoise as she

worked to create the play. It would need to cover these four concepts, incorporate several participatory moments, and tell the narrative story of the agoraphobic scientist. Though she had passed on generating the probe activities during the five events, once she began to write, she asked us to participate in an exercise to help her in the writing process. To me, this seemed to serve a similar purpose as the probes, though it was done over email rather than face to face. She wanted us to explore who these characters were, and what it looked like when they interacted, and to describe three different scenes with other characters. For example, my hope was that there would be a scene in which the protagonist faced her mentor, a mother figure who was also a successful woman in science, but who succeeded during a time when women simply weren't invited to participate in the sciences. Itai envisioned a scene in which the protagonist explained her agoraphobia to a therapist, who would ask her questions providing opportunities for her to explain her feelings through scientific phenomena. We each submitted our scenes, and Aoise worked to incorporate them all into the first draft of the play. The script she developed followed the dramatic arc of a romantic comedy. During our early meetings, Itai, Melanie, Max, and I had played with the idea of structuring the play as a mystery, or even a murder mystery, but the structure did not match up well with the concept of agoraphobia. By the end of the process, it was unclear to me how we arrived at the romantic comedy structure, though it was clear that all of us had agreed to the structure.

Aoise arranged the various pieces of the puzzle we had collaboratively created together, including all of the scenes we had suggested to her. Aoise also structured the play around three



interactions.<sup>22</sup> Each of these concepts were deeply related to the idea of emergent phenomena, and these activities were meant to convey specific instances in which local rules between individual objects or entities lead to novel behaviors at larger scales. For Itai, the idea was that there was still mystery in the kind of science in which he was engaged. Scientists were working to understand how patterns emerged out of local behaviors, but they did not yet have clear answers. These interactions were, thus far, vaguely defined as 1) momentum conservation, 2) the behavior of individual neurons, and 3) something Itai called the Kadanoff Decimation. This third activity was particularly ill-defined because the scientific theory Itai was trying to express, the Kadanoff Decimation, was so complex that time and time again, his explanations failed to clarify the phenomenon for us. Eventually this concept came to be renamed “group normalization theory.” The explanation continued to elude us, which should have indicated to us that it would be difficult to clearly articulate the concept to an audience. The problems we had developing the explanation and interaction for this particular participatory moment harken back to the conversation we had in which I tried to explain the engagement model to the group. This theory was so complex that it really did seem to require a high level of specialized knowledge to grasp what Itai was saying. And even when we did grasp it, our understanding felt tenuous and fleeting. Itai recognized this and wondered how to distill a Nobel Prize winning theory into a five minute description of a phenomenon.

During the writing process, Aoise contacted Itai on several occasions to help her “get the science right.” She would often send him excerpts from the script with notes for him to fill in scientific

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<sup>22</sup> Formerly there were four, but the interaction that depicted how a single neuron worked was eliminated because it was discussed in the interaction that depicted the way neurons formed thoughts.

information. She said she would then adjust the dialogue he had written to put it into the characters' voices. While I was not privy to their back and forth, I witnessed similar exchanges during the rehearsal process when she would change or edit the script to more accurately reflect Itai's explanations of the scientific phenomena.

The final script and performance began with audience members following a set of rules printed and inserted in their programs. The rules, following conservation momentum, dictated how they crossed the grid on stage to get to their seats. The show then began. The story followed Amanda, an agoraphobic scientist who studied emergent phenomena, as she fell in love, battled her panic disorder, and helped her former advisor plan a wedding. Over the course of the show, she first stops the action to explain how neurons work together to form thoughts using metallic balls that are passed around the audience, and then later enlists the audience to act as guests at the wedding to help her use scientific theories to help develop an optimal seating chart (see Appendix A for an extended synopsis I co-authored with Aoise Stratford, the playwright).

### **Rehearsing and Performing *Emergence***

While I focus here primarily on the creation of the script for *Emergence*, the end result was not just the script, but a full performance, cast with students from the University, designed largely by faculty from the performing arts department, and performed in a black box theatre in the University's performing arts center. Problems with the script became evident in the rehearsal process, prompting Aoise to do several iterations of rewrites. Often the performers (four undergraduates and one graduate student) were unable to understand or deliver the scientific jargon, which indicated we had to rethink the phrasing so the audience would understand as well.

In a way, the cast became our first public, and their ability to comprehend what they were saying pushed us toward clarification. In addition, the interactive moments involved some level of improvisation, so the actors would have to be comfortable enough with the concepts to respond to audience members on the fly. Creating a loose enough script for this while giving the cast the words they needed to feel comfortable proved to be more challenging than we had anticipated. The moments leading up to these scenes were originally meant to be improvised, but required more and more pre-written explanations as the rehearsal process progressed.

While many of the issues stemmed from the interactive moments, one issue with the plot itself warranted considerable rewrites. Itai had envisioned the main character, Amanda, talking about her problems with agoraphobia to a therapist. Their exchanges would provide opportunities for her to explain some of the scientific phenomena behind the movement of crowds through discussions with a therapist about why she is not able to maneuver in crowds. The problem with this strategy was not in the explanation of the science, but in the dramatic structure of the play. The problem, as we discussed it, was that without tension, the relationship between Amanda and the therapist fell flat. It did not make for good drama or comedy. But in order to create dramatic tension between these characters, the therapist needed to be more than a receptacle for Amanda's emotions and thoughts, he had to work against her in some way. Aoise's solution to this was to rethink their relationship. Instead of Amanda willingly going to therapy to share her emotions, Aoise incorporated a new motivation for the therapist: He was writing a book on agoraphobia, and Amanda had signed an agreement with him to participate as a subject in his study. She therefore was obligated to attempt to manage her agoraphobia using his methods. This new

tension between the two of them meant that both the therapist and Amanda had a stake in their conversations, and they both had a separate agenda regarding what got discussed.

This reworking is of interest to me because it was one of the few major revisions that was made for artistic reasons rather than for fidelity to scientific knowledge. The therapist as a character had been one of Itai's ideas for a scene, and had been a way to provide exposition about Amanda's agoraphobia as well as her work as a scientist. But now, scientific explanation was weighing down the story, and the exchanges between the protagonist and the therapist were not strong enough to pin on Itai's scientific explanation. One reason for this was a lack of conflict between Amanda and the therapist, which was rooted in a lack of motivation for the therapist. Though science may have been able to maintain all of the truth claims, the implication was that if the story did not somehow also ring true, the scientific information being presented would not matter.

In some ways, this conflict might look similar to Maren and Itai's attempts to generate fairness or balance; however, it was not approached in the same way for a number of reasons. In *Dance of Scales*, Maren seemed to be seeking freedom to express herself; here, Aoise was addressing a flaw in the script that was driven by a need for exposition mixed with an underdeveloped character. Solving this problem seemed more akin to figuring out a puzzle or riddle than it was to providing opportunities for expression. On the one hand, both *Dance of Scales* and *Emergence* began with ideas about integration and ended up operating through different forms of negotiation. On the other, there was an enormous difference between Maren's desire to create something expressive and free from constraints and Aoise's drive to create a clear, compelling

narrative. In *Dance of Scales*, the tension was between open and constrained expression, while in *Emergence*, it was a tension between two different sets of constraints. Though I classified constraint as explanation in *Dance of Scales*, seeing these two competing sets of constraints forced me to reconsider. Explanation may be one way of constraining expression, but narrative might be another. After all Aoise, like all playwrights working (at least in part) in narrative realism, hoped the audience would follow the story and see the characters as she had envisioned them. Constraint, then, is a placing of restrictions on how a text is to be interpreted for by an audience. These restrictions may be loose or tight. For example, Aoise may have had a stricter set of restrictions when constraining interpretations of *Emergence* than for another play because she was working within Itai's scientific explanation and her own narrative realism. And Aoise is not alone in her ability to impose restrictions. As a director, Melanie may choose to impose a narrower set of restrictions. Regardless of how carefully a presenter may craft a message to be interpreted in a specific way, audiences have the power to follow or push back against these constraints. When Hall writes about negotiated and oppositional decoding, it is this freedom to which he is referring. The audiences for these plays may or may not follow the narrative Aoise or the explanation from Itai, but *Emergence* was written to funnel their interpretations into a specific set of meanings.

Though this tensions was different, the collaborative team from *Emergence* still spoke more about integration at the beginning wound up abandoning that hope. Rather than the linear progression I witnessed in *Dance of Scales*, the transformation from integration to negotiation was a complex, winding path. The increase in the number of collaborators, the larger production team, and the added complexity of the relationship between participation and narrative made for

much more subtle boundary work that protected territory that was less obvious than epistemic knowledge or focus on stage.

### ***Emergence and the Audience***

*Emergence* had full houses for all four performances. Each performance was held in the same location, so that variation in performance was not radically impacted by factors like house-size or environment. Different audiences seemed to be rowdier than others, and one performance was thrown off slightly by actors losing their place and then jumping a section of the script. The creative team (Itai, Melanie, Max, Aoise, and I) held post-show discussions after each of the performances, both to answer questions from audience members and to elicit discussion and feedback from the audience. For the first performance, I also attempted to conduct exit interviews with people who left the theatre before the discussion, but these audience members were reluctant to answer questions and appeared to be in a rush, so for subsequent performances, I focused my efforts on questioning remaining audience members as a group rather than individual exit interviews. No doubt the fact that these audience members were being asked questions by the creators of the show in front of other audience members had an impact on how they answered our questions. This larger focus group approach was not what I had originally intended, but I did not find it more problematic than the initial plan of interviewing small groups as they exited. Our aim was not to find out if they approved or disapproved, but to better understand what kind of meaning they made from the performance. As such, it made little sense to try to question people who were not interested in speaking with us about the performance rather than listening to people who were eager to talk about their experiences.

Those who remained for the discussions were enthusiastic about sharing their impressions and ideas. The four post-show discussions varied widely, but some themes overlapped all four discussions. First, to the audience, there was a clear tension between the narrative, which they often associated with art, and the interaction, which they often associated with science. Some found meaning in the transition between the two, like this audience member who spoke about understanding the broader picture from the second interaction:

For me [the second interaction depicting neurons] was the moment when I got a theme for the larger play, which was the difficulty of focusing on single interactions to extrapolate some kind of critical mass phenomenon... I felt like it was fun to play with, but also, a very tangible model of the kind of emergent phenomenon that you're kind of playfully mapping on to the stressors of human life.

Other audience members were able to recognize metaphoric connections between the science and the narrative. One audience member noted that the grid represented the world and, "the way in which we interact with that grid creates reality and experience." Another audience member suggested that "your experiences and your everyday, they sort of create these other personalities in you that you may see colliding." One member found what they described as a mirrored relationship between the audience's experience and Amanda's:

Our journey of understanding what was being presented to us intellectually scientifically mirrors Amanda's journey of applying the knowledge she already has toward the social interactions she has such difficulty with. We mirror her in that way, our understanding of applying social situation that we're already here to observe and incorporating a new understanding of scientific theory into that is sort

of equal and opposite to her approach to understanding social interactions and viewing them through the scientific knowledge she has. And we're sort of the mirror of her that way, the same way she's a mirror of herself.<sup>23</sup>

Some audience members focused on the relationship between rules and life:

To me the play was about the emergence of construction of three dimensional experience in life, and Amanda's difficulties are no more her own than any of us who has to do something they're not familiar with without a set of rules to play by, and playing the rules, discovering those rules, for me, is what life is, so the fact that it is also science and dance [unintelligible]. Thank you, I really enjoyed it.

Others did not move as easily between the narrative and science.

It was a great story. I loved seeing a play about a scientist [...] as far as what she was doing as science, I taught science and I was confused. I sort of understood the neuron thing but got confused from the directions [...] and the cards lost me entirely [...] but I loved the story.

But often those who had trouble understanding the interactions said they still found them engaging, and even enjoyable. Some audience members spoke about the way the interactive activities helped connect viewers to the story and "put the viewer in it," while others spoke about the potential for helping them understand physics concepts. One audience member noted the way the interactions afforded them the opportunity to mingle with other audience members, a connection one usually isn't permitted in live theatre.

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<sup>23</sup> The audience member was referring to several scenes in which the protagonist addressed herself in a mirror. In these scenes, her mirrored self was portrayed by another actor.



One couple went so far as to declare that she was there for the story and he was there for the science, so she paid attention to the story and ignored the interactions while he focused on the scientific concepts and interactions and ignored the story. Gender stereotypes notwithstanding, these responses show that the interactions could be viewed in two ways: as opportunities for directed science learning or as ways of drawing people into the story. As we developed the performance, we had discussed several overlapping reasons for including participatory experiences; thus, these multiple understandings of participation had been encoded into the performance. The audience could choose which they read, or could attempt to read multiple meanings for the participatory experiences.

Throughout the four performances, we noted a resistance by many to the interactive experiences. Several audience members entered through a side door and sat in the back, bypassing the first interaction, and did not participate in the subsequent interactions. Some moved along the grid quickly, with the clear intent of getting through without having to interact with another person. Some of these spectators were known to be regular theatre-goers familiar with the department and space, suggesting that any discomfort with participation did not stem from unfamiliarity. Though there were plenty of people willing and eager to participate, it is difficult to dismiss the clear indication that many people come to the theatre expecting to be passive spectators. Similarly, in our discussions with the audience we sensed a resistance among some to thinking too much about the experience. As one audience member noted, many students left the theatre before the post-show discussion began. As discussed above, those who were questioned as they exited the theatre were polite but brief with their answers or they declined to speak. Those who answered often displayed body language that, to me, seemed to suggest that they were

uncomfortable with the idea that they would have to answer questions about what they had seen. This could, of course, be for a variety of reasons, about which I would not wish to speculate. These unknown factors are likely common, however, and therefore, part of the story of audiences and presenters is the story of audiences who are unwilling to engage. Despite our interested and talkative minority, it was clear that most audience members expected, and many even wished for, a passive role in the performance.

### **Realism, Participation, and a Feminist Tightrope<sup>24</sup>**

Melanie was interested in the introduction of rules as an art form: “I was so excited by [the idea] we could create rules for the audience and have them experience something new and unique. I hoped the whole project would evolve like that, into some new art form-ish thing.” Melanie also spoke about her hope that the show would follow this format, but that the team ended up compromising into narrative because it offered a way to keep audiences invested. For Itai, narrative offered a chance to bring his scientific material to an audience in a way that would be more emotionally appealing, noting, “one of the things that is very hard with the science I do is to make an emotional connection.” He was wary of experiential theatre, noting, “there has to be some kind of value to the audience members,” and that he had not encountered many instances in which experiential theatre had been successful in making him care about the subject. Though he wanted to try something new and to work with participation, he was determined to do so within a story to which the audience could relate. In the end, Melanie reflected on this decision as a good one, saying “I’m not sorry we told a story because we reached more people.” Both Melanie and

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<sup>24</sup> Some of the concepts in this section are drawn from an unpublished manuscript I co-authored with Aoise. Much of the writing on feminism and realism is a condensed version of arguments developed with Aoise for that manuscript.

Itai were drawing on the tacit knowledge that audiences were used to narrative theatre and thus would respond more favorably, despite their own excitement over participatory, experimental forms during the creative process. But they were also grappling with these different forms of expression, and it was still clear that the sets of constraints they wanted to impose on those forms of expression were, to some degree, at odds. What was possible in participatory experiences was its own form of constraint. Over and over, in our conversations about participation, the discussion turned to what audiences would realistically do and what was “fair” to ask of them. At the same time, our collective excitement over participation as a means of providing a novel, memorable experience was not diminished. As Itai reflected after the performance, “when I think about ways of conveying information to the lay public, you know, you could give a lecture, but only theatre would allow for an interactive experience the way that they had.”

Aoise classified the style in which she crafted the narrative aspect of the show “narrative realism.” It was clear to me that she meant something akin to Busselle et al.’s (2008) definition, “coherence and logic within a particular fictional context” (p. 270). This internal consistency (as opposed to fidelity to external understandings of reality, which becomes problematic for constructivists or post modernists) became very challenging to cultivate, in part because it was difficult to weave the interaction into the narrative, but also because there seemed to be a tension between dramatic tension and didactic exposition, as was the case with the example of the role of the therapist and the relationship between he and Amanda. The technical difficulty in blending narrative and explanation was coupled with another challenge: the rules by which Aoise was writing the play, i.e. the constructs we provided when she began and the suggestions for scenes

she asked us to write, were an unruly puzzle. During a post show discussion, Aoise summed up these difficulties:

AOISE: What was challenging for me was the collaboration. Normally for me, when I start a play, I have a question that I'm worrying away at and I start there and kind of unravel and off I go. Here there were all sorts of constraints already in play. So for me writing the play was a little bit like walking the grid [a reference to the first interactive moment in the show]. You know, I walk the grid and I bump into something and I think hmm, how am I gonna get around that. I don't like exposition, but we need all this exposition. Ok, I'll turn this way and see what happens.

This statement was in response to a question about what the greatest challenges and the greatest rewards were in the process. It is worth noting that Aoise went on to say the same problematic collaboration she described above was also the most rewarding part of the process for her.

There were differences of opinion about what would be deemed 'realistic' and how much of a suspension of disbelief the audience would be able to muster. For example, there was a scene in which Amanda, the agoraphobic protagonist, goes rollerblading with her new romantic interest, Robert. In the original script, the two of them rollerblade side by side; however, in the rehearsal process, Itai was concerned that it was unrealistic for anyone to learn to rollerblade in a short amount of time. After some discussion, the scene was directed such that Amanda trips and her love interest catches her. Aoise expressed deep concerns for this interpretation, which seemed to imply that Amanda needed to be rescued. The idea that a strong female character play such a historically weak role in a love scene was far more troubling to her than the audience's willingness to accept that she excelled at rollerblading too quickly. I must admit I agreed with

Aoise's misgivings, but recognized that it was not only Itai, but also the actors who had interpreted the scene this way, and our experiences with the actors thus far indicated that they were already stretching themselves far beyond their own experiences in playing these roles. The comfort of a familiar trope in a romantic comedy (our chosen genre) seemed little to ask of us when we were asking them to take on themes and concepts that were so far beyond their current understanding.

The example discussed above was but one of many in which Aoise's feminist ideals were compromised. When Aoise joined the project, she did so with a feminist agenda, though she and I did not explicitly discuss this agenda until much later. Prior to her involvement, the four of us had originally decided on a strong, female scientist as a way to promote the image of successful women in the sciences, but our discussion of feminism and intentions to create a feminist performance did not extend far beyond this initial impulse. Aoise came to the table with a stronger feminist perspective, which I appreciated. Early in her part of the process, she discussed the fact that the image of a strong woman scientist we hoped to create was undercut by the disorder we assigned to the character. When we chose to address agoraphobia, it was because the panic disorder could be connected to the movement of crowds as well the behavior of neurons, linking the character deeply to emergent phenomena, the concept Itai had been so excited to represent on stage. But the proximity of a serious mental illness to the stereotype of the hysterical woman had escaped us in our excitement to tie agoraphobia to emergent phenomena. The result was a tightrope of sorts, in which the character of Amanda would have to be portrayed very carefully to maintain the idea of a strong woman at the top of her field who, simultaneously, was a troubled individual with an anxiety disorder.

But a discussion of feminism in *Emergence* must go deeper than Amanda's character, into the problem of our choice to use realism as well as experimentation side by side. In science studies, many scholars focus on ideas like objectivity and fact in light of the constructed nature of knowledge, and the partial perspectives from which both scientists and the public create and exchange knowledge—and feminist scholars are no exception. For example, in "Situated Knowledges," Donna Haraway dismantles the idea of objectivity, arguing that it is historically, geographically and culturally contingent; however, she is unwilling to let go of the desire to "talk about reality with...confidence" not cynicism (1988, p. 577). Haraway notes that "'realism' [as an epistemological position]...has proved a rather poor way of engaging with the world's active agency" (p. 593). Feminism in theatre asks similar questions: what constitutes the real and who gets to decide that and how it might offer a site for engagement is at the heart of what might be considered the feminist question in theatre. It is by now widely accepted that feminism is not a singular position but that there are feminisms. Logically then, these ideologies tend to be aligned with different kinds of feminist theatre that tend to privilege some theatrical elements over others. Patricia Schroeder offers the following summary in her essay "Realism and The Feminist Critique:"

Liberal feminist theater...depicts female heroes in traditionally structured (often realistic) plays, allowing women's historically suppressed voices to be heard on stage; the...radical feminist approach, which replaces linear dramatic structures with more fluid or circular forms, thought more accurately to reflect female experience; and the materialist feminist approach, which disrupts linear narratives to expose the cultural construction of seemingly natural roles like gender, race and

class and to emphasize the material conditions that promote various oppressions.  
(Schroeder, 1996, p.21)

These different forms of feminist theatre are not necessarily fixed or mutually exclusive categories, but they indicate a discussion of form—and realism in particular—has been an important part of the debate over what constitutes feminist theatre. For some feminists what defines feminist theatre might have less to do with form and depend more on focusing on women's experiences and offering positive role-models (both of which *Emergence* did). For others, realism regardless of subject matter is entirely antithetical to feminist representation. Case and Aston describe realism as a prisonhouse:

Realism, in its focus on the domestic sphere and the family unit, reifies the male as sexual subject and the female as the sexual 'Other'. The portrayal of female characters within the family unit—with their confinement to the domestic setting, their dependence on the husband, their own defeatist, determinist view of the opportunities for change—makes realism a 'prisonhouse' of art for women, both in their representation on stage and in the female actor's preparation and production of such roles. (2008, p. 124)

Although realism in contemporary theatre might not focus on the domestic, the formal problems of purporting to reflect a 'real' world and therefore reflecting the gender roles that 'real' world assumes to be a given, remain.

Other feminists, such as Jill Dolan, reframe the problem to put the male spectator at the center, rather than the male performer. Dolan argues that realism problematically presents a reality that is singular, and stable, and in which, consequently, the spectator's individuality is "subsumed under an assumption of commonality" (Dolan, 1988, p. 1). Such a commonality privileges "the

ideal white, middle-class, heterosexual, male spectator” and in so doing “perpetuates cultural assumptions that are oppressive to women” (p. 18). As Haraway notes, “vision is always a question of the power to see” (Haraway, 1988, p. 585) and clearly Dolan’s critique of the relationship between realism and the feminist spectator has some overlap with the problems of finding a feminist version of objectivity which seeks to accommodate “no-nonsense commitment to faithful accounts of a ‘real’ world” while acknowledging the partial and contingent vision of the observer, who may not be male or white or heterosexual or middle-class (p. 579).

Despite these arguments against realism, it remains a form in which many feminist playwrights work, in part because more traditional and conventional forms of theatre continue to reach larger audiences than avant-garde and experimental work, which Melanie, Itai, Max, and I discussed early in the process. The choice to flee the prisonhouse of realism or to stay there and rattle the bars might depend on which and how many audience members might be reached, and for what purpose we might address or engage them. And in our case, it seems as if we attempted both at once. Schroeder argues convincingly for a reassessment of the feminist uses of realism, pointing to the oversimplicity of aligning experimentalism with feminist ideology and to the tendency of many feminist playwrights to transgress formal boundaries by using some non-realistic elements in plays that are otherwise considered to be realism. She asks: “Must all elements commonly attributed to realism be in evidence if a play is to be deemed realistic? Are there varieties of the form, perhaps ‘realisms’?...is feminist drama necessarily experimental, necessarily antithetical to realism?” (Schroeder, 1996, p. 16).



In our case, it was easy to see narrative realism as highly constraining, especially when it had to follow the logic of the puzzle we had created in the character of Amanda, find ways fit explanations of Itai's work, and incorporate and make sense of the participatory, experimental moments in the play. While narrative realism may have seemed a prisonhouse, especially with the perimeters established during the creative process, these constraints were less rigid than the scientific explanations, which were thought of not as a constructed, contingent, contextual body of work, but as something "real" that needed explanation and demonstration. The epistemological position of realism embedded in the science to be communicated differed from the narrative realism that drove the development of the story of *Emergence*. Narrative realism required characters who were consistent and behaved in a way audiences could accept and a story that was, at the very least, plausible, while epistemological realism (realism to the outside world, specifically to the science world) stemmed from Itai's work as an experimental scientist, and was required during the experimental as well as the narrative moments in the performance. In the *Dance of Scales* case, I noted that tension was between constrained and unconstrained expression, and I called the constrained expression sought by Itai explanation. Here, I suggest that explanation was but one way to constrain expression. In this particular case, explanation is not an accurate enough term. Because there were competing ways of constraining expression, and because we took a realist approach to scientific knowledge (an approach taken by the team, not just by Itai), it might be more accurate to say that expression was limited to the expression of two different, but overlapping, versions of reality. The first, based in narrative realism, sought to constrain the interpretation to a particular story, while the second, epistemological realism, sought to constrain interpretation to a particular system of knowledge and set of facts. These

competing yet related and overlapping ways of constraining expression formed the primary tensions around which the creative team had to navigate until we developed the participatory moments in the performance.

The third set of constraints, the participatory rules audiences could easily and willingly follow to demonstrate Itai's principles, was, itself, contested because Itai, Aoise, and Melanie all had such different approaches and reasons for creating interactive moments. In spite of these varied reasons and approaches, the participatory rules were meant to help blend the epistemological realism and the narrative realism without compromising either, even though the participatory moments broke form the narrative realism and greatly oversimplified the epistemological realism. *Emergence* worked within but against formal conventions, which is common in mainstream feminist drama. The resulting form used narrative realism in combination with experimental techniques to make the apparatus of performance transparent, and acknowledge the audience. This created cracks in the narrative, for example, Melanie mentioned that some audience members wondered how Amanda could so easily converse with the audience during the participatory moments while maintaining her character's agoraphobic tendencies. Because feminism was not the only, or even the foremost, agenda, but rather one ideological position from which the production was created, the play between narrative realism, epistemological realism, and participation was not presented to the audience as a feminist move. Moreover audiences may not have seen what remained of the feminist agenda—the strong female character at the center of the narrative—due to the choices that Aoise felt undermined her power. Already, Amanda's strength was vulnerable. The choice we made to incorporate agoraphobia had put us in danger of invoking stereotypes of the hysterical woman, and now, small actions, like the choice

for Amanda to fall and be “caught” by Robert during the rollerblading scene may have all but erased any overt feminist agenda. The complexities of Aoise’s feminist stance played a role in the negotiation between her narrative and the interactive moments, but they took a back-seat to the agreed upon motive of fostering understanding or appreciation of Itai’s research. The discussions we ended up having about the script or performance as a work of art were always embedded within the context of getting the science right and staying true to Itai’s work, so there was a hierarchy of form to which we adhered: first, to epistemological realism, and to Itai’s work, followed by narrative realism and internal consistency.

### **Conceptual Boundary Objects**

As I suggested above, the participatory elements were also constraining. Early on, the differing ideas behind these experiences mirrored the differences between expression and explanation. At first Melanie wanted to create an interaction in which audiences shaped the meaning of the experiences, while Itai wanted to use participation as a way of imparting knowledge as he understood it. While the participatory moments were heavily tied to epistemic realism, to be effective, they also had to work within the narrative reality of the script, and incorporate audiences in a compelling way. Thus, these three forms of constraint—narrative realism, epistemological realism, and participatory feasibility—created a complex terrain upon which we had to chart the course of the production. This rocky terrain made for the creation or use of a series of improbable boundary objects that were less objects and more concepts. The idea of a boundary object being something other than a tangible artifact is in line with Star and Griesemer’s work on boundary objects; however, until this project, I had not encountered a

situation in which the primary boundary objects shared by a group were all conceptual rather than tangible. The most obvious, and perhaps the most discussed boundary object was the primary scientific concept around which *Emergence* was built: emergent phenomena. But several other concepts formed interesting fodder for our discussions, and I find it helpful to think of them as boundary objects in order to examine the kind of boundary work in which we were engaged.

### **Emergent phenomena**

The scientific concept at the center of the project became a boundary object in the way that most scientific concepts do when they are introduced into projects like *Emergence*. The scientific knowledge, as Itai understood it, was based in a precise technical language that we did not speak, so the concept had different meaning to the rest of the creative team. Though we worked hard to understand the nuances of emergent phenomena and spent time with Itai as he explained it in a number of different ways, our understanding was not the same as his. To us, as to the larger team of actors and designers, and as we have seen with some of the responses from the audience as well, the concept of emergent phenomena became a metaphor for understanding our place in a crowd. For the actors the concept became a way of understanding their characters and the plot so that they could do their jobs. One actor spoke of the feeling of not being cast in a role, but of being, instead, in an ensemble. To some degree, I believe he was speaking about the structures embedded in the performance that were drawn from the scientific concepts we were working to communicate. More tangibly, the actors and audience resonated with the idea that the scientific

explanations of emergent phenomena, especially the interactive exercise demonstrating momentum conservation, as metaphors for some kind of human, personal difficulty.

## **Rules**

Rules came up early and often in the collaborative process, and were discussed throughout the development of the interactive moments. I believe they became an important object for audiences to wrestle with as well. For Itai, the rules just exist. Once they were established, outcomes were inevitable; predictions, exact. Rules were a hard truth up against which we all must bump. For Melanie, they were constructs; toys that could be played with to devise different kinds of theatrical experiences. The rules provided a structure within which the audience could interact with one another and with the performance. But, as Melanie pointed out, the audience may not understand the rules, or they may choose not to follow them. At the very least, they would need to be guided through some kind of process in order to learn them. Itai did not foresee such trouble with rules because, to him, they were observed and recorded rather than invented. I am not sure how to characterize the way audience members understood the concept of rules, other than to say that there were two sets of rules to which they responded. First, there were the rules or conventions of going to the theatre: take your seat, be quiet during the performance and attend to the actors. These were unspoken and understood by most audience members. But the second set of rules, the rules for the interactive moments, were a mystery before the audience members arrived at the theatre and perhaps still a mystery after the performance. Some worked hard to try to understand the rules of each interaction, but the rules were often too complex for them to grasp in the time we allotted and the information we provided. And some audience members

actively worked against the rules, refusing to participate in the interactive moments at all.

Audience members had individual reactions to rules, as Melanie predicted, but, as Itai hoped, for the most part they were able to follow the rules closely enough to generate interactions that matched Itai's predicted outcome fairly closely. I observed the phenomenon myself when I watched the audience enter the theatre from overhead. I was seated in "the booth," a room overlooking the theatre from which the stage manager and other technicians run the lights and sounds, and I was able to videotape the audience negotiating the rules and finding their seats. Sped up, the video reveals the beginnings of the patterns Itai sought.

### **Audience Participation**

Audience participation was a particularly fraught boundary object. Our individual understandings of what we meant by participation were not clear or fixed, and so the overlapping definition became troublesome. I don't believe most of us had a clear idea of what we meant by participation at the beginning of the process; we just knew that we wanted the members of the audience to interact with one another and with the production. Itai's understanding of participation was strongly rooted in demonstration, as discussed in Chapter 4, but Melanie's hope of a new "art form-ish thing" did not necessarily align with Itai's tactic of asking audience members to embody particles or neutrons and to play out a predetermined result that mirrored results seen in laboratory experiments. The role of participation was further complicated by my own background and my understanding of engagement in informal science learning as well as science communication, and by Aoise's work with interactivity as a feminist rejection of realism. We each approached this production with our own agendas and these agendas were reflected in

our approaches to interactivity. Where Itai was interested in using these interactions to explain the science, Melanie was driven by the artistic idea of creating a conversation throughout the process, and Aoise was interested in how interactions might upend the status quo of narrative realism.

We also considered the way the audience might understand participation. We often discussed the traditional role of the audience as passive observer. Melanie said she actively works against this kind of passivity; she finds a connection between passivity and what she calls amnesia, or the failure of theatrical events to live on in the memories of the audience. But these audience members' expectations should not be dismissed as unfair. This is the commonly accepted relationship between audiences and performers, particularly for performances, like *Emergence*, that take place in traditional performance space. In fact, it might be fair to say that this is one reason many people enjoy going to the theatre.<sup>25</sup> Though Melanie was excited about interactivity, she was simultaneously aware of the dangers, and concerned about the choices we were making. She cautioned that the audience should not feel manipulated into participating, and that it would be hard to get them to participate. The point of this was not to say that these kinds of participatory experiences were not worth the time we spent time trying to create and implement them, but rather, that it would be important to situate our expectations about what audiences would and would not do in a theatre, and what was fair of us to invite them to do during a performance, within the context of what they were used to and expected.

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<sup>25</sup> Alternately, it might be fair to say that theatre has its roots in ritual, and its ancient ancestors were not events in which anyone sat passively.

The disconnect between the exploratory interactive events we created for ourselves during the development process and the demonstrative participatory events we ended up creating for the rest of the audience was not lost on us. The probes designed for each stage in the development of the play achieved for the creative team the kinds of experiences some of us hoped to provide for the audience; however, these kinds of activities might not reflect the experiences the audience wished for themselves. Importantly, the goal of the probes was open exploration of concepts and ideas; that is, we used these to *develop* the rules we ended up providing for the audience. Despite multiple other agendas, the ultimate agreed upon goal of the interactive moments staged for and with the audience was to demonstrate a specific principle; to *perform already established rules*. This distinction meant that in the end, the audience was not allowed the same kind of opportunities for open interpretation that the show's creators were allowed during their much lengthier process. But, there is no clear indication that they would have wanted such freedom.

## **Conclusions**

Whether or not audiences were able to navigate the narrative and epistemological realities, and whether or not they were willing participants in the interactive elements, were central themes in conversations among the show's creators and audience members. Each of the five collaborators had our own reasons for participating in this project, and for working with audience participation. Where Itai was interested in explaining and demonstrating science in new ways, Melanie was driven by the artistic idea of creating a conversation throughout the process, Max was interested in developing a model for future collaborations that created performances as forms of science outreach, Aoise was interested in how interactions might serve theatrically and



politically to level a gendered playing field, and I was interested in better understanding the relationship between the artists, scientists, and audiences involved. Despite our own agendas, we all deferred to the broader goals of fostering interest in a specific scientific field and understanding of a specific scientific concept, but we pursued that interest through our own experiences within our own fields.

As in *Dance of Scales*, boundary work was at the heart of the process, and the characteristics of the boundary work changed over the course of the process. Early boundary work, during the probe activities, was largely constructive. But it seemed that, even more so than during the development of *Dance of Scales*, science won epistemic authority early in the process. This was due, in no small part, to the NSF grant writing that coincided with the early process. Once we determined the scientific information would be at the center of what we created, the remaining boundary work progressed differently than it had in *Dance of Scales*, but the end result was a similar process of negotiation. The issues of balance and fairness got expressed through the attempts to work within the constraints of narrative realism, epistemological realism, and participatory demonstration. We were at odds over what was more internally inconsistent, how to manage the transitions between narrative and demonstration, and how to incorporate agendas other than the primary concern of science communication without compromising that concern. The negotiation once again often took the form of how each of us envisioned connecting to the audience, both through interactions and through narrative. For example, the discussion surrounding the scene in which Amanda rollerblades prompted the question of whether we should defer to physical plausibility or character development. We had established that we were committed to creating a performance that conveyed scientific information, but many questions

about the performance remained, and many of the artistic choices we faced were made more difficult because of that commitment.

Once again, the tension between the expression of narrative realism and the expression of epistemological realism is reflected back in the responses of the audience. Audience members interpreted the performance through their own lens, and often they had “either/or lenses” rather than “and” lenses. This does continue to point toward collaborations that were being pulled in different directions rather than cohesive, integrated performances, but I am not convinced that this either/or split diminishes any potential benefit of seeing the performance. The audience members who stayed for the discussions of *Emergence* offered quite rich explanations of what they saw and what they thought about the main point of the performance. This suggests to me that, at least for some of the audience, it was a worthwhile experience. Whether or not they found value in the show is not going to be sufficient to say whether or not they learned anything, nor will it help assess whether or not they have greater interest in the scientific concepts than they did before. And this does not even begin to address the problem of self-selection: many audience members were there because they were already interested in the scientific subject matter. In fact, the audiences who remained seemed to be affiliated with either the arts or sciences in some way.

When considering *Emergence* alongside *Dance of Scales*, a pattern begins to emerge. In both cases, early discussions revealed a desire to create something new. For Maren, it was to create something that was neither art nor science by integrating the two, and for Melanie, it was a desire for the interactive elements of the performance to develop into a new form of expression. In both cases, these early hopes were followed by an attempt to fit the project into a formula that is

appropriate for informal science learning, which was even more apparent in *Emergence* than *Dance of Scales*. This was followed by a tension or even frustration with the role art was playing in the collaboration. In *Dance of Scales*, the struggle was between open expression to be freely interpreted by audiences and constrained expression meant to be understood in a specific way. In *Emergence*, Aoise's tightly knit world came to blows with Itai's same desire to explain his work so that it could be understood. While there was much less outright negotiation about whether art or science would take priority when, there was a shared sense of the continued difficulties found in attempting to marry the narrative realism, epistemological world, and the participatory moments. The pattern seems, to me, to be a move to try to develop integration (constructive boundary work), followed by a process of negotiation, or what Gieryn might consider normal boundary work, during which the groups found some irreconcilabilities within their points of view and their aims for the work. These two forms of reality could be mapped onto expression and explanation, becoming yet another version of the boundary between art and science. Narrative reality, a form of expression, required the narrative to exist as a self-contained world, while epistemological reality required the narrative to conform to Itai's understanding of the scientific knowledge, mapping on to explanation.

Another notable difference in the boundary work done for these projects was that the team from *Emergence* was mainly concerned with negotiating the product of their collaboration, rather than worrying about the process, while Maren and Itai focused on the way they interacted with one another as well as the their interactions with the audience. This is likely because the process for *Emergence* included extended boundary probe activities as well as shifts in the group over time. First, there was the addition of Aoise, the playwright, and then later, the production team and

cast. By the end of the project, the performance was, in many ways, a traditional theatrical process, and it was housed entirely within the performing arts department. The similarities in these two cases do not, in and of themselves, make the case for a larger pattern. After all, Itai was the primary scientist involved in both projects. Though his attitude toward science is not out of the ordinary for an experimental physicist, the projects might be drastically different with a different scientist, whether that person was in the same field or not. It is not without importance that in both shows the science easily established epistemic authority despite the fact that there was only one scientist involved, and a number of artists. Though science claimed epistemic authority in these cases, the resources, including space and audience, are provided largely through the arts. In chapter two, I discussed the nature of social worlds and the potential for a boundary world to be created through these collaborations. To me, it does not seem as though the social worlds at play merge, but rather, remain adjacent. There is structural and economic reality that not only prevents a new boundary world from forming, but also impacts the success (at least in terms of the ambitions of the collaborators) of the projects themselves.

When I began this project, I hoped to find a boundary world in which art and science participated equally. Neither of these projects alone constitute a social world. The closest I might have come to finding an actual boundary world might have been Light in Winter, the festival at which *Dance of Scales* was performed. However, at least in the cases of *Dance of Scales*, *Emergence*, and Light and Winter itself, there were a set of structural obstacles that prevented the worldness necessary for a social world. As I saw with both *Emergence* and *Dance of Scales*, the funding sources (or even unfunded appeals to funding sources) would often shift thinking toward informal science learning rather than performance. Funding sources for art/science are not

plentiful, and when we wrote these proposals, explanation became deeply embedded in goals of the project. Further, there was no career advantage for Itai to participate in these endeavors, and while Melanie felt such strategic partnerships might be valuable to her department, ultimately, there was no indication that there were benefits other than the inherent growth and reward in collaboration and production for anyone involved. Itai may have developed new ways of talking about his work to popular audiences, but speaking to public audiences did not become a valuable skill for him. Similarly, Melanie and Aoise may have benefited from working with new people in new ways, but *Emergence* did not become a valuable asset to the theatre world.

In his original work on art worlds, Becker noted that the audience played a significant role in the formation and maintenance of the art world. In both of these cases, the audiences seemed to be divided in their interpretation of what they had seen, and that division often coincided with the social world to which they belonged. While *Dance of Scales* played briefly with the idea of participation, it was a driving principle of *Emergence*. One of the more impactful observations in this case has been the way the audiences responded to the participatory moments in the show. Not just what they said when they were asked, but their behavior surrounding being asked to participate. Many were reluctant, and still more reluctant to discuss their participation. Those who were willing to try were often confused about the rules and even the purpose of the interactions. In initial discussions, Melanie had hoped the audience participation would somehow impact the performance itself, but after having witnessed audiences responding to the demonstration activities, I wondered if such participation was feasible. Though the participatory experiences were telling, they were not necessarily surprising. After all, many of our conversations about audience participation from the beginning were focused on how much was

too much to ask of an audience, what we could reasonably expect them to do, and how to create an environment that would allow them to feel safe to participate. From our previous experiences working in theatre, we knew that modern audiences were used to being spectators rather than participants, and that shifting that dynamic would meet with resistance.

When our suspicions were confirmed, it presented an opportunity to revisit one of the key assumptions made by the public engagement model: that the public would be eager, or even willing, to engage. Though this assumption has been questioned by scholars in the science communication field, much of the critique has been framed in terms of how much the public is willing to engage in civic events like citizen juries. Early in the engagement movement, some (for example Durant, 1999) noted public demand for greater participation and called for a reimagining of deliberative democracy. Later, however, scholars recognized that one of the pitfalls of this public demand for information and participation did not necessarily mean the public was eager to devote the kind of time and energy to scientific policy initiatives that deliberative democracy would demand (Nowotny, 2014; Sturgis, 2014; Wynne, 2007). But my experiences suggest that even within engagement as interaction, or informal science learning initiatives, we might be overestimating just how active the audience wishes to be. Additionally, we may be underestimating audiences by assuming that it takes visible acts for them to be active. Though we, as practitioners and researchers, may not be able to see or measure activities, internal meaning-making processes may be valuable and valid forms of interaction.

## CHAPTER 6: FRONTSTAGE

Since I began working with artists and scientists to create performances, those artists and scientists have been pondering audience participation. Participation played a small role in *Dance of Scales*, and a larger role in *Emergence*, but it was also considered or attempted by many collaborative teams that came before them. This seemingly universal fascination with participation, along with our attempt to thoroughly incorporate participation into *Emergence*, and with the resistance we anticipated and found during the production, prompted me to think about what audience participation meant, why it was important, and what its relationship was to public engagement. I was also moved to think about what kind of activities would be enjoyable and inviting for audiences. The success of the probe activities I'd been developing with project creators prompted me to think about the kinds of tasks developed for probes: qualitative, ambiguous, playful. I began to develop an idea for a sort of portable probe; a smartphone application (app) that could be used in performances and presentations to foster the same kinds of interactions as the prompts I used in my probes. Of course the use of such an app would be highly dependent on the presenters who used it, and the choices they made, so even if it was designed for such use, there is no guarantee that it would, in fact, be used as I intended. I thought, instead, I could focus on creating something that would be flexible enough for the kind of use I had envisioned as well as a variety of other uses presenters might find useful.

I further developed the concept for the app, which came to be called Frontstage, through a proposal for a USDA Hatch grant to use iPhones and iPads to develop a system for audience participation. The initial proposal stated that it would be an audience participation system that would facilitate engagement as well as create opportunities for assessment during presentations.

By engagement, I had in mind engagement as interaction, as described in informal science education literature. That is to say, opportunities for learners to participate in, and shape, their own learning. Practically, this meant providing ways for audiences to answer open-ended questions that would enrich their experiences and invite them into the process of meaning-making. Again, I knew this was a tall order, and that it would eventually be up to the presenter users of the system to use it in engaging ways. As for assessment, often audiences in informal science education are asked to provide answers to questions regarding their experiences to provide evaluative feedback to the presenters, either about their presentations or about the audience's learning. Assessment is often one of the uses of existing audience response technologies, so it would make sense for this system to be flexible enough to be used for assessment as well as engagement.

Once I was notified that we had received the funding from the USDA, I assembled a team of undergraduates to develop the software. The team members changed over time, as undergraduates graduated and went on to other opportunities, but at any given point in the development of Frontstage, there were at least three undergraduate research assistants working to develop and test the Frontstage system. I remained the principal designer and researcher for the project, though initial research of existing audience response software was conducted by some of the undergraduates and by one additional graduate student.

As we began to plan and develop the system, I found that the twin goals of engagement and assessment (each in itself daunting) created more questions than answers. Can both goals be accomplished at once? How do presenters make decisions about how to use audience



participation? Are they thinking of specific assessment or engagement goals? How are they defining engagement or assessment? Are they even thinking in terms of engagement or assessment? These questions were as much a part of the development of Frontstage as the set of iPod and iPhone applications my team developed and the people who took up the apps in different and unexpected ways. Frontstage became a way to use design to investigate these questions of assessment and engagement, while at the same time working to develop a practical, usable audience participation system. Part of the research done through Frontstage focused on whether presenters would seek opportunities to engage, assess, or both, or to do something else altogether. Rather than build specific mechanisms for either engagement or assessment, we decided to use ambiguity (Gaver et al., 2003) to the greatest extent possible so that we could learn by watching how presenters used Frontstage. In other words, we did not design specifically for engagement or assessment, but rather, tried to envision different kinds of interactions between a presenter and an audience and asked presenters to define the kinds of experiences they created from those interactions.

In this chapter, I will first describe the process of designing Frontstage, and then will focus on three case studies of Frontstage use, each in a different field, with very different approaches, aims, and logistical needs. In addition to these three in-depth case studies, I will draw on insights gleaned during early user tests both in the lab and at three science themed talks at a local café. The uses of Frontstage were far different from anything I might have anticipated when I began designing the system, but the insights these uses provided help to further develop these ideas of open and constrained expression, explanation, and, because the focus is now on the audience, the analogs to expression and explanation, interpretation and understanding. Though these originated

in discussions about the differences between the arts and sciences in *Dance of Scales* and *Emergence*, they proved to be relevant when considering the different uses of Frontstage and the ways presenters and audiences spoke about these uses. The discussion in this chapter will focus on whether audiences were asked to interpret or understand, or, in some cases, step into the role of the presenters and express their ideas. I will also examine the relationships between interpretation, understanding and expression.

### **A Typology of Audience Response Technologies<sup>26</sup>**

Before discussing the design process for Frontstage and describing the final product, I would like to place this system in the context of existing work being done with audience participation.

Existing systems, which are most often called audience response systems (ARS), are abundant, but when I began Frontstage, the idea of using smartphones and tablets for such systems was still relatively novel. Most of the systems discussed below require some kind of device to either measure one or another aspect of audience members' behavior or to provide ways for them to respond. As smartphones become more ubiquitous, and are more often equipped with a variety of methods of input that range from motion sensing to typing, they become obvious candidates for the implementation of new ARS. These phones also carry the advantage of familiarity to both audience members and presenters, who will have to be comfortable enough with the technology to instruct their audiences on how to use it.

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<sup>26</sup> Content from this section was taken from an unpublished manuscript. Madeline Smith, a graduate student in Information Science who was interested in audience response technologies, contributed to the research and synthesis done to write about existing audience response technologies.

I am troubled by the use of the word ‘response’ in ARS literature. It seems to me that those who coined the term envisioned situations in which audiences were responding to a prompt rather than interacting with the presentation. Though I adopt the terminology used in the literature for this section, I continue to distinguish between these systems and Frontstage, which I consider a participation system rather than a response system. I briefly examine these existing systems in part because when I set out to develop Frontstage, my team and I conducted this literature review to better understand the landscape we were about to enter, and in part because the presenters who used Frontstage were at the very least aware of the more common ARS, like the iClicker. These systems, in some way, informed their understanding of what it meant to use a technology that helps audiences communicate with presenters.

Existing technologies go by several names, and involve several kinds of interactions. We use the term ARS to encompass all types of systems, though most references to ARS are referring to what are also called electronic voting systems (EVS). EVS, like the iClicker, have been gaining popularity on college campuses (Kay & LeSage, 2009), and have been used to some extent in informal science education (for example, in museums and during public lectures) (Kay & LeSage, 2009; Moss & Crowley, 2011). These systems primarily allow audience members to answer multiple-choice questions by pressing a button, although some can also be used for more open-ended questions. Constant response measurement (CRM) systems have been used in politics as well as in social science research and allow users to provide a constant stream of data (Biocca et al., 1994). Biometrics, like eye tracking and galvanic skin response (GSR), has been used as a means of measuring things like focus or arousal (Lang, 1994; Thorson, 1994).

Most of the relevant literature discusses the use of ARS and EVS in classrooms and informal settings. ARS were largely used in one of three ways: to encourage participation, test knowledge, and/or elicit feedback from the audience (Moss & Crowley, 2011). Improvements have been documented in classroom experiences, student learning, and instructor's ability to assess learning (Kay & LeSage, 2009). However, such improvements do not occur without careful effort on the part of teachers or presenters. CRM systems, on the other hand, involve constant input that may not necessarily draw a significant amount of the user's attention. Such systems are often used to elicit feedback responses rather than to engage users. The idea behind such systems is to visually display the subtle changes that audience members signal in their mental state for researchers to measure, such as persuasion, attention (indirectly), "hedonic responses" (e.g. emotional responses to television, like the dials used during political debates), and semantic processing (Biocca, David, & West, 1994). Biological ARS, like GSR (Latulipe, Carroll, & Lottridge, 2011) and eye tracking (Thorson, 1994), require no direct attention from the user (although some of these measures may still draw attention to themselves) and are usually used by researchers in psychology and related fields.

### **Designing Frontstage**

We began the process with early experiments in the lab. First, I created a worksheet with prompts that were, once again, similar to those found in a cultural probe (see Figure 10). I gave the worksheet to six people (two undergraduate students, three graduate students, and a postdoctoral scholar who were all participating in the same course, a seminar in advanced topics in interaction design) and asked them to fill in the worksheet as they watched a short video by physicist,

mathematician, and science popularizer Brian Greene. After the video, I gave the participants a few minutes to finish their worksheets and then conducted a focus group to ask them about their history of watching informal science media, their motivations for watching such media, and their experience of watching the video while filling out the worksheet. The worksheet contained several boxes with prompts including “Ideas I have” and “One Word Responses,” and “Draw What You See.” These prompts were arranged in boxes, much like a comic book, to help give the idea that there was no linear progression, but that they could skip around between them. One of

Audience Participation iOS App: SAMPLE USER TEST AND INTERVIEW QUESTIONS

<i>Interesting things</i>	<b>ONE WORD RESPONSES</b> <i>keep a running list of your responses to what you are watching Try to write an response every minute or so.</i>
<i>things I don't understand</i>	
<i>draw what you think of what you see</i>	
<i>ideas I have</i>	
	<i>I will remember</i>

Questions? contact [mkh46@cornell.edu](mailto:mkh46@cornell.edu)

**FIGURE 10:** *The first activity in the lab to begin to get users’ input into the process of designing Frontstage. This worksheet was given out to six students as they watched a short science themed video. Their discussion provided formative information about audience participation.*

the most discussed aspects of the exercise was the difficulty they had with focusing on the tasks in some of the boxes while they watched. For example, one student, an undergraduate, felt that she could complete some of the tasks, like drawing or writing things down, but could not be asked to think and listen at the same time.

D: The questions in general I thought were really distracting, I was thinking of an idea, or thinking of something I didn't understand, but I can't do both.

ME: You couldn't listen and think of an answer at the same time?

D: Yeah and think of an answer. I can write and listen, and I can draw and listen, but I can't think and listen.

Some of the other participants nodded, but one, a postdoctoral researcher, noted that he watches these kinds of programs (his example was the classic television series *Cosmos*) specifically to be provoked, and that he will often stop the programs and talk to his wife about what he's seen.

I don't watch these things for learning or enjoyment, I watch them to be provoked. I want to either think new thoughts or think old thoughts in new ways. Find different ways of seeing things; find different ways approaching the world. I think that it's not necessarily that I want the video or the speaker's way of seeing the world, but listening to that often puts me in a mental place where I can then sort of step outside of my usual way of approaching situations and start thinking of things from a different perspective that's somewhere in between where I usually come from and where they're coming from.

What I found interesting was that this response came out of a discussion in which I noted that the participants were speaking about what would have helped them learn from the video or what would have helped them enjoy the video more. So I asked which was more important. Notably,

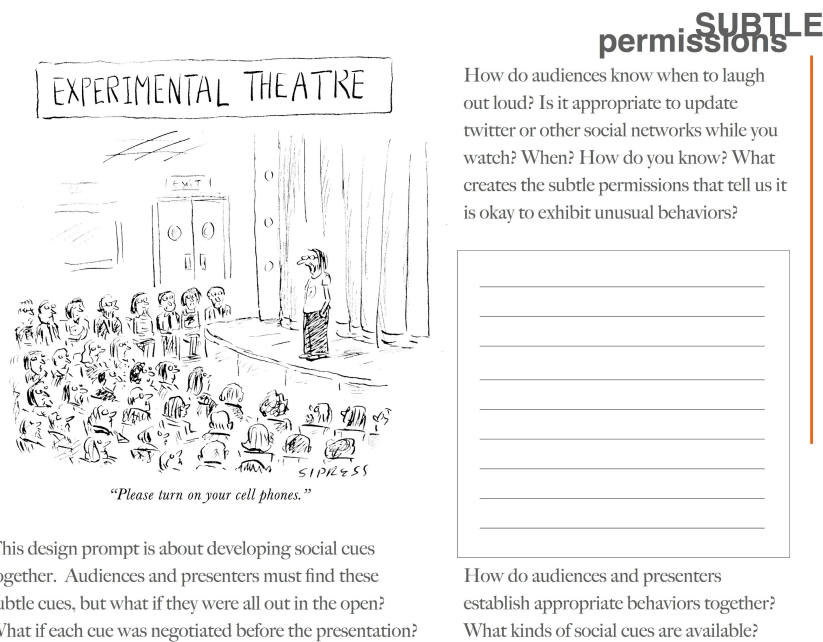
two people (one of them being the speaker of the above quote about seeking provocation) said that they did not distinguish between learning and enjoyment. In reflecting on the answer above, I begin to wonder if, for people who do not distinguish, attending to an informal science event, like the video we showed, was similar to attending to a performance. In other words, was the cultural experience of art fundamentally different for these people than the cultural experience of science? For others, learning and enjoyment were very different things. They suggested that they would not normally seek out experiences like watching popular science programs. Relatedly, there was also disagreement about whether people wanted open-ended questions or options from which to choose, suggesting that even among this relatively homogenous group (all students from several related departments), people envisioned for themselves very different ways of being an audience member. Though this was a small discussion with only six students, I could not help but think I had stumbled upon something interesting about informal science learners: the potential to equate learning (or in the postdoctoral researcher's case, having new ideas) with entertainment.

These early tests also included working with an undergraduate team to emulate some existing ARS to understand how they might inform Frontstage. For example, we worked with two small test audiences, one for a video from NOVA Science Now featuring astronomer and popularizer Neil DeGrasse Tyson and another for a guest lecture on science books. To simulate the dials often used in CRM (constant response measurement) for political debates, the iPods were waved up and down to move lines on a screen up and down. Since the tests were with small audiences, we could display each of the lines on a screen in front of the presenter rather than an aggregate of all of them. After discussions with the test audiences, we felt that this would not be a suitable

module for Frontstage for several reasons. First, because the audiences for the preliminary tests were used to seeing these dials used in political debates, and saw them as judgmental and polarizing rather than helpful or insightful. Second, many said they did not associate science lectures with strong emotional responses or with agree/disagree responses. In our efforts to maintain a degree of ambiguity, we did not specify what moving the iPods the up or down meant, but the test audiences saw them as approval/disapproval, agreement/disagreement, or like/dislike.

At the same time I began experimenting with Gaver's design workbooks (Gaver, 2011b) to develop inspiration for Frontstage. Specifically, I aimed to reach beyond the kinds of activities I found in my review of existing ARS. Workbooks are meant to be "collections of design proposals and other materials drawn together during projects to investigate options for design" (p. 1551). Gaver describes workbooks developed in the early stages of the process as tools that allow designs to develop slowly over time, through expressions of multiple ideas, often generated by multiple team members. The workbook I created for Frontstage consisted of several different design inspirations that were explored through visuals and text (see Figure 11). Each page contained a theme, such as open & closed, rhythm & feedback, and subtle permissions, along with visuals and text exploring that theme. The design workbook was meant to open the design space and move away from traditional ARS technologies, but the ideas generated using the design workbook proved to be too complex for our resources. For example, we explored the possibility of using the system to make subtle, rhythmic sounds as audiences moved their iPods, creating a rhythm for the presentation based on audience members' interpretations of the presentation. The time and skill required to develop such a system was simply too great for a small, exploratory study.



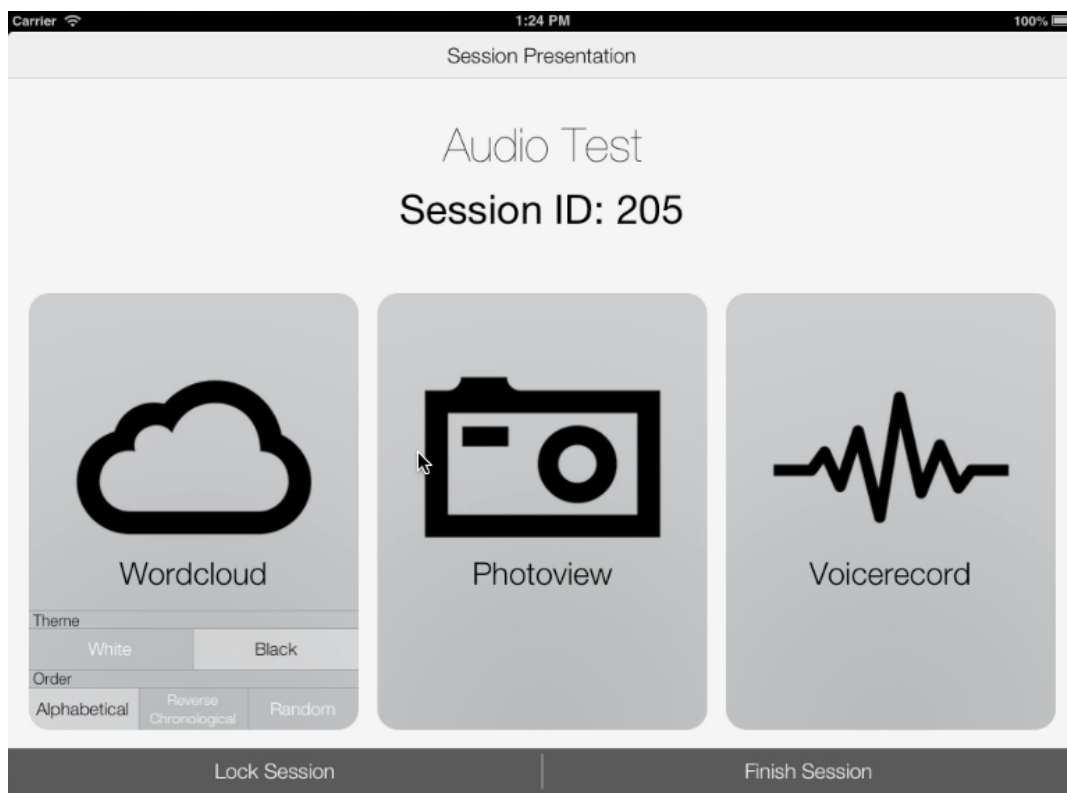


**FIGURE 11: A page from the design workbook. This workbook was envisioned as a series of provocative design prompts. Because I was not collaborating with other designers, I asked potential presenters and audience members to go through the prompts with me and respond to them.**

In the end, with the resources we had, I decided to focus on the kinds of interactions already afforded by the iOS platform, meaning we built Frontstage around the ability to input information through photographs, text, and audio recordings. Using these inputs, we developed several modules for Frontstage, which are discussed below. These were built iteratively, through continued tests in the lab and at a local restaurant that hosted the Science Cabaret, a monthly event in which different people, mainly scientists, present something about their work or life that is related to science. For example, the first Science Cabaret Event at which we tested Frontstage featured two presenters, a scientist who spoke about his work with fruit flies and a science communication and science history scholar who spoke about the relationship between science

and the public. At the second, a woman spoke who had expertise in pickling and preserving food, and she was followed by a scientist who spoke about the chemical reactions that occur during fermentation processes. On another evening, Frontstage was used during an event Science Cabaret called “Ask an Astronomer” in which five astronomers were available to take questions from the audience.

### The Frontstage System



***FIGURE 12: The home screen for the Frontstage Presenter Portal.***

The system that resulted from the multiple iterations used in the tests described above works with two iOS (Apple’s operating system for iPods, iPhones, and iPads) applications. The first, Frontstage itself, is an audience interface that can be uploaded to iPhones or iPads. The second,

called Frontstage Presenter Portal can be uploaded on an iPad. This app can be used to set the parameters for each presentation (called a session in the app) and to display the information collected from the audience. The Presenter Portal is designed so that once a presentation has started, the data from the Frontstage app modules can be projected or displayed to the audience. In the end we settled on four modules, each using a different input, and each developed without specific goals or standards for use, and, to the best of our abilities, without preconceived ideas of how presenters would use them.

### *Module 1: Wordcloud*

This was the first module built and tested outside of the lab, largely because it was the technically the simplest to create. Wordcloud was based on the growing popularity of sites like Wurdle that count the number of times a word is repeated and create a visual representation of a document in which the words used most often appear larger.



**FIGURE 13:** *A Wordcloud developed during a talk about food preservation at the Science Cabaret*

from a single text source, we decided to create a word cloud from various words and phrases entered by participants.

### *Module 2: Mosaic*

The mosaic module was the most technically challenging for us, and perhaps the most creatively displayed. Put simply, it was a visual multiple choice module. Presenters could input different images for audience members to choose from, and those images were then displayed as a mosaic on the iPad. Images that were selected by more audience members became larger and moved to the center of the screen, while images that were selected by fewer audience members were smaller and were distributed around the central images.



***FIGURE 14: A Mosaic developed during the Ask and Astronomer event at the Science Cabaret***

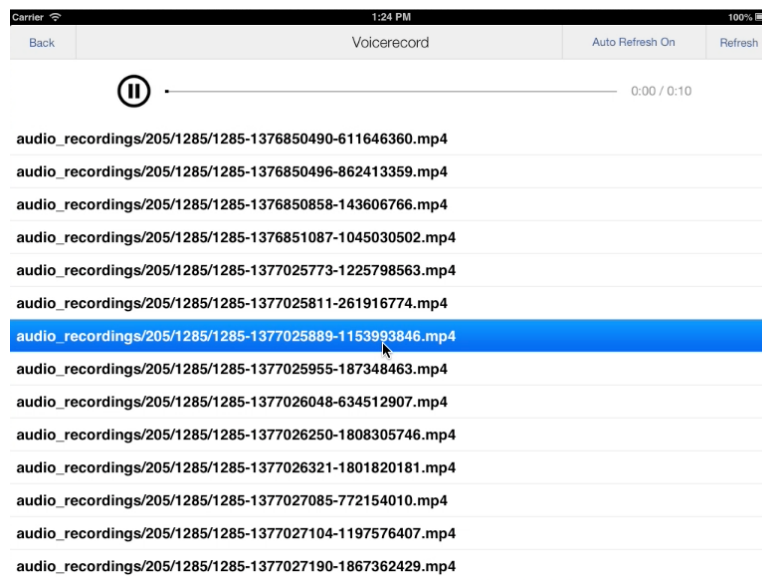
### *Module 3: Photoview*

This module allowed audience members to take photographs and then displayed these photographs in a grid in the Presenter Portal. Each image could be selected and enlarged in front of the grid to be examined on its own.

### *Module 4: Voicerecord*

Voicerecord allowed the audience to record audio for up to one minute. The audio was then displayed as a list in the Presenter Portal. Each file could be played separately.

The Presenter Portal was designed to provide minimal input into the Frontstage app, meaning, there were not many variables other than which modules were available to audiences in any given presentation. Presenters could create a session in the Presenter Portal, and Frontstage users could enter the session number to begin interacting with the presentation. Each session could include any combination of the four modules, and each module was somewhat customizable,



**FIGURE 15:** A set of Voicerecord audio recordings displayed on the Frontstage Presenter Portal

mostly in terms of superficial modifications. The background of the Mosaic and Wordcloud could be either black or white, and the words in the Wordcloud could be arranged in chronological, alphabetical, or random order. The mosaic module was the most customizable because it allowed presenters to upload their own images from which the audiences could choose.

Our aims for such a bare-bones system were twofold. First, we wanted to ensure there were as few barriers to entry as possible for presenters. Though I knew the Presenter Portal would take more time to learn than the Frontstage app, I hoped not to create a cumbersome interface or a time consuming experience. Second, and for me more important, goal was to create an open-ended system that invited presenters to interpret how it could be used, rather than dictating to them how it should be used. That desire stemmed from the original concept, in which we tried to think through a system that would foster engagement and provide opportunities for assessment. To create a system that was that flexible and still simple, I decided the questions, prompts, or other mechanisms for beginning the interaction with the audience should stem from the presenters rather than the software. There was no way to program particular questions into either app, only for audiences to input their phrases, choices, images, and recordings, and for those to be displayed via the presenter portal.

In each of the three Frontstage cases I present below, I conducted close observations of, and in depth interviews with, the presenters as they worked with Frontstage. Part of these observations took the shape of training presenters to use the system. Working so closely with presenters allowed me to learn a great deal about what assumptions they were making about their

audiences, what they aimed for by using Frontstage, and how they viewed their relationship with their audiences. While the dynamic between us was different, the level of access to their thought processes was similar. However, as I suggest in Chapter 3, insight into audience members' motives and perceptions proved to be much more elusive. Initially, I believed I would be able to use the same method of research for each of the cases described below, but I found that because I wanted to understand how Frontstage was used, the decisions about how to use Frontstage were made under vastly different circumstances, taking use of the system in vastly different directions. As a result, I found I needed to adapt my methods for each case. In each case I will describe the steps taken to observe and gain insight into the audiences' interactions with Frontstage and with the presentation or performance for which it was used.

### **Frontstage Cases**

Despite my best efforts to design an open system, I did envision Frontstage as a system that would be used in settings with live audiences; one that would be used by those audiences during the presentations, and that would be displayed to those audiences by the presenters. The presenters who used Frontstage challenged these preconceptions. In two of the following cases, audiences did not use the app during the presentation, and, in fact, did not use the app themselves, but rather, were approached by an intermediary who maintained control of the device. In another case, the presenter used the devices to help the audience collaborate in small groups. Further, while all of the presenters used the iPad to display the input from audiences, one of them did not draw attention to that display, so some audience members did not know of its existence, impacting their views on what they were doing when using the system. I will admit

that at first, I was disappointed by some of these choices. I know that, as a researcher, I should not be disappointed: all of the choices are data of some kind. But as a designer, I had hoped to see audience members tapping away on iPods to large, real-time displays, and that simply did not happen. In the end, however, these choices proved to be immensely revealing about not only the ways presenters viewed their audiences, but also, how audiences envisioned their own role.

### **Frontstage at the Museum**

Holly, an entomologist-turned-science-communication professional who runs a public science department associated with a university, decided to use Frontstage at the grand opening of a new wing at the museum connected to her university. The opening itself was a twenty-four hour, museum-wide event consisting of special activities and scientists who stood ready to interact with museum-goers throughout the night. Entomologists with giant cockroaches and other bugs invited guests to touch or hold the insects. Holly wanted to use Frontstage to offer something unique to visitors to an area of the museum, which, under normal circumstances, was a functioning laboratory within the museum.

Since our work relates to biodiversity and sort of encouraging our audiences [to think about] biodiversity, we wanted to think of some way during the opening that we could sort of assess to where our audience is on biodiversity, in a way, or engage them in a conversation about biodiversity. Partly so that we can find out where we needed to go but also partly because we wanted to do—we thought that could be some kind of fun activity that somehow would relate to the opening.

Holly enlisted several of her colleagues, and each of them came up with ways to use Frontstage. At the first meeting in which they discussed Frontstage (it was on the agenda at a larger



meeting), I was asked to Skype in to the meeting to discuss how the system worked and answer any questions they had. I shared with them the four modules and described how they worked. After this meeting, Holly took charge of their Frontstage project and collected their requests for questions or prompts to be used. I arrived the day before the event and Holly and I set up five different sessions, using Wordcloud, Mosaic, and Voicerecord. It took all five sessions to incorporate everyone's questions. Two of the sessions focused on biodiversity, two focused on endangered species and conservation, and one focused on dinosaurs. Holly's modules were those that focused on biodiversity. She based some of her questions on a report on Nature Deficit Disorder<sup>27</sup>, which is "a label used to address the increasing cost to children as they are increasingly deprived of direct contact with nature and the experience of unstructured free play in the out-of-doors" (Driessnack, 2009, p. 73; Louv, 2008).

Holly was quite conscious of the phrasing of her questions, and focused on asking open-ended questions. She said she wanted to phrase them so that visitors did not assume there was a right answer, suggesting she was much more interested in learning about their ideas and experiences than testing their knowledge. She indicated that some of her questions were a kind of "barometer for gauging understanding" regarding topics associated with biodiversity. For example, she asked them to explain what the terms "web of life" and "biodiversity" meant to them. She asked them to choose the photograph that best represented biodiversity for them from an array of images that included a rainforest, a coral reef, and a bellybutton. She also asked them to list their favorite places in nature and why they liked to be in nature. Holly's collaborators' questions ranged from

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<sup>27</sup> Holly did not directly identify the specific report she had read; however, Louv (2008) coined the term, and has written extensively on the phenomenon.

open ended to straightforward multiple choice items. For example, the dinosaur session featured the use of Voicerecord to ask people (specifically children) to make the kinds of sounds they thought dinosaurs might have made, and used Mosaic to ask visitors to correctly identify a dinosaur from a series of images that featured several seemingly prehistoric creatures and a bird. This particular question was interesting in that the presenters did not build in a way to “close the loop” or to provide the correct answer, which was meant to be the image of the bird.

Because the museum was so large and they predicted nearly a hundred thousand visitors to the grand opening event, Holly was reluctant to hand out the iPods to museum-goers. In the tests I had conducted at the Science Cabaret, I had taken audience members’ Drivers’ Licenses and IDs as collateral and returned them when they returned the devices, but Holly was not comfortable with this, so she and her colleagues decided to use volunteers to act as intermediaries with the visitors. They enlisted the help of graduate students, college students, and friends to roam the museum with the iPods running Frontstage and elicit responses from visitors (the audience in this case study) by asking questions and inputting the results themselves. I had envisioned people interacting directly with the devices, and at first, I was disappointed. But I found the issue of trust was not limited to concerns over theft of the devices, but also over the possibility of inappropriate material making its way into the display. But an interesting opportunity came out of this desire to curate the audience input in order to prevent inappropriate content. I was able to observe the dynamic relationship between the volunteers and guests; a relationship that came to play a central role in this story as well as the next Frontstage case.

My observations of the interactions between the volunteers and visitors revealed a different kind of science communication from what I've studied thus far. There was a kind of intimacy to the interactions. This was a personal, conversational experience, rather than a performative, participatory experience. Volunteers were listening to and responding to what the visitors said on an emotional level. For example, in response to a question about what the term web of life means, a visitor said, "It means that we're all interconnected to one another." To which the volunteer responded, "That's great! I like that." "You do?" asked the visitor, apparently pleased that he had given an answer that moved her. This exchange was recorded by Frontstage, and the participants were well aware they were being recorded, but they were not speaking to the device. Instead, they were having a conversation with one another. Often the initial question or prompt given to the audience member acted as a starting point for a conversation. The volunteers had a wide range of backgrounds, knowledge about the subjects, and styles of approaching visitors, so some would impart their own knowledge about a subject, and others would engage in light conversation about the topic of the question or about the museum-goers' visit in general. Some would correct visitors or explain topics related to the modules. I noted that the prompts were loosely scripted, and the instructions given to the volunteers were informal, so volunteers could potentially ask very different questions and give different information, which would lead visitors to make certain assumptions about the purpose of the questions and the way their answers would be used.

Volunteers roamed throughout the museum with iPods, but the visual display of their combined answers was limited to a monitor in a lab on the second floor of the museum. The different word clouds and mosaics were rotated on the display, so visitors seeking the displays that reflected

their participation may not have been able to find them. In addition, since much of this endeavor ended up being improvised in response to unpredictable circumstances, and the crowds at the lab that housed the display were often a bit overwhelming, Holly and the volunteers decided they should spread themselves throughout the museum rather than remain close to the display. Once they were decoupled from the display, some did not end up discussing the displays with visitors at all, characterizing the interaction as part of a research project or as an opportunity to test new software. At first, I was concerned that because of the lack of continuity in the administration of the test, I would not be able to learn about patterns or understand any broader themes, but in the end I found all of these inconsistencies compelling, as they revealed something about the way the volunteers as well as the visitors understood the exercise.

Peoples' perceptions of the activity were shaped by whether or not they knew about or saw the display. If they were looking at the display when they chose their answers, they would look for their own answers and express delight when they saw them. If they were approached far away from the display, they would treat the exercise as a survey they were answering for a social scientist who was squirreled away somewhere analyzing their answers. This means that audiences (and volunteers) were thinking either of assessment or engagement when they participated in the use of Frontstage. If they perceived it as a tool for engagement, to them, the point of the activity was often their own self-reflection, and they perceived a tool for assessment, they felt they were helping the museum or a group of researchers understand their knowledge or perspectives, or they were helping test Frontstage system itself. No one indicated they perceived both roles in the system, making this choice seem like a binary one: Frontstage could be an engagement or an assessment tool. It was not easy to tell how they felt about these activities from

their surveys, however, most of those who felt they were participating in a reflective exercise seemed to enjoy it. One audience member even expressed gratitude to the team for providing such an opportunity, writing on the back of his or her survey, “Thanks for making us think about biodiversity.”

Initially, we planned to observe the use of Frontstage and to conduct small focus groups to discuss it with the people who used the system; however, because volunteers used the devices, interviewing the groups with whom the volunteers interacted became problematic. It was as if they were being asked about their experience about being asked about biodiversity. This apparent redundancy was cumbersome and detracted from the audience experience, so we decided to create a short, open-ended survey instead. The survey asked questions about what the visitor was asked to do, what they thought the museum would do with their answers, and what they thought the purpose of the activity might have been. While most participants ended up saying they thought the experience was some sort of research for the museum (some called it a survey, making the survey in which they were calling it a survey seem redundant to say the least), or test of an iOS app, which it was, at least for me. Other common answers included the belief that the app was designed to test knowledge, or to improve exhibits or get grants. Finally, a few people suggested the experience would help them to think. One user answered the question “What do you think the purpose of this exercise might have been?” with “think about how we perceive nature”; and then answered the question “How would you describe this to a friend who was not here today?” with “It helped me reconsider how I think about nature.” The diversity of answers reflected the diversity of information and framing provided by the volunteer intermediaries, but it also reflected the ambiguity left in the wake of a traditional presenter, or a presentation in which

the results were displayed. In the end, though, this non-traditional exercise in audience, or visitor, participation, and this ambiguity of purpose proved to be interesting and enlightening for me, but, it would seem also for the participants, many of whom noted that the experience was some combination of quick, easy, and fun.

### **Frontstage on Stage**

The second in-depth test of Frontstage was its use in a performance called *Long Ago in May*. The performance was a University production, directed by a faculty member, Melanie (also the director of *Emergence*), which was performed primarily by students with one exception, a professional actor who appeared to be in his forties. The performance was not a traditional play, but rather a series of vignettes exploring themes of different experiences of love. This style, called “collage theatre,” also offered minimal dialogue, included projections, and involved voiceover dialogue delivered in several languages with video subtitles. Much like Frontstage itself, the performance was, in many ways, ambiguous. As a reviewer for a local paper commented, “Are the characters becoming friends, falling in love, cheating on each other? Their lack of dialogue allows us to interpret the relationships the way we want” (Petro, 2012).

In addition to observing the creative process by which the director, designers, and actors decided how to incorporate Frontstage, after the production ended I conducted an in depth interview with the director and an extended focus group with the cast and crew. I also observed the ways audience members interacted with Frontstage, which was, once again, through intermediaries. Then, along with an undergraduate student research assistant, I conducted brief, informal exit interviews after each of the performances. I also attempted to use the short survey created for the

museum, but audience members were in a hurry to leave after the show, so the exit interviews proved to be the best way to solicit audience perspectives on the use of Frontstage. Again, we focused on learning what their assumptions were about the purpose of the interaction and on what (if anything) the interaction provided for them.

The use of Frontstage was discussed early and at length in monthly, then in biweekly, production meetings with the director, designers, stage manager, and technical director. We observed these meetings, which began seven months prior to the performances. No other use of Frontstage required such detailed planning, but this level of attention to the physical production is typical for a theatrical performance. One of the reasons we sought out such a use for the system was to see what kind of thought and planning went in to different kinds of presentations. In addition to detailed discussions of how the production should use the Frontstage system, there were many logistical discussions about how it would fit into the technical production. Who would “run” the system? Where would the display be projected? These questions were addressed by a team of designers, each with a stake in how using the Frontstage system would affect the aesthetics, logistics, and meaning of the performance. Early in the process, the lighting designer expressed concern over the spill of light from the devices in the audience. What would it look like, to audience members with and without iPods, to have small sources of light throughout the audience? Would it be distracting? Would it change the mood? After this discussion, the decision was made to use the devices before the show and to project the display at several points during the show. Once again, I found I was surprised by the way the presenters had decided to use Frontstage. I had not anticipated separating the audience’s experience in such a way that their active engagement was disconnected from the visualization of their collective input.

In addition to the decoupling of the use of the system and the projection of the results, the production team made decisions that provided a unique research opportunity. Like Holly and her colleagues, this team made the decision to control the use of the devices. The actors would go into the lobby before the show, in full costume, and solicit input from the audience. They would ask audience members to give them a phrase, rather than a single word, that describes love or they would ask them to choose from a series of photos which best depicted love. They would then type it in themselves for it to be projected at certain points during the show. This protected the devices themselves from theft, and protected the production from inappropriate content. They also decided not to use Wordcloud as a traditional word cloud, but rather, to seek unique phrases from audience members so that all of the words appeared roughly the same size, and a series of phrases and stories resembling poetry were projected and scrolled across the set during the performance. In *Dance of Scales*, the difference between expression/interpretation and explanation/understanding fell along the art/science divide, and the division in *Long Ago in May* was similar. Because this was unambiguously a performance, the main agenda seemed to be completely focused on expression/interpretation rather than understanding, supporting the original distinction between Maren's and Itai's work.

This use of the iPods and Frontstage also provided a unique interaction between performer and audience. By interacting with the audience and soliciting input from them, these actors were “breaking the fourth wall” before the show began. Although actors were costumed, they were not addressing the audience as specific characters, but as themselves. Some cast members felt this ruined the element of surprise, or interfered with the suspension of disbelief for the performance,



while others felt it was helpful. One cast member noted the audience missed a key moment of anticipation:

I was kind of reluctant for it to be like the first interaction that we had with the audience. I think it kind of took away kind of like the special surprise elements of like you know, I know—cause this is my first time being in a show as opposed to a spectator and know that as a spectator I really look forward to like the suspense of “Ooh I wonder what kind of costumes they’re going to be in? Or like what they’re gonna be like...” And I feel like we didn’t have that moment to do that because our introduction was so casual, kind of.

While another observed the way it put him at ease on stage to have had the interactions:

I liked it because—and I’ve done it before in the theatre—I’ve sold muffins to audience members and then later had the audience pelt us with the muffins (...). So I like the deeply breaking that fourth wall so much so that you’re out finding out, you know, people’s love lives and making jokes and things like that. I have always for some personal reasons struggled with performance anxiety—we all do—but I do... and [interacting with audience before the show] breaks that down for me. I am aware that I have had a lucky charming little conversation that’s private and funny with a handful of people that I’m going to be performing for and it does some little psychological trick to me that lets me feel like I’m in my living room or that I’m among friends.

Another cast member added that after these interactions that she felt that the audience was “rooting for her” in a way.

While I was able to delve deeply into the way the performers, who were the intermediaries in this case, felt about Frontstage, once again I found that the audience members who used Frontstage

were not very interested in reflecting on that use. After the performances of *Long Ago in May*, they were often eager to leave the theatre, and reluctant to talk about the performance or their participation. I believe part of their apprehension stemmed from the unique nature of the performance itself. It seemed as though they did were not comfortable with their ability to talk about a non-narrative play, though I do not know for sure what their motives were. When they did speak with me or with my research assistant, most often they said they noticed the phrases they gave the actors before the show scrolling during the performance. Many audience members responded positively to the exercise, saying it was fun to see their words on the screen, or that the exercise got them thinking about love before the show. Their perceptions of the purpose of the activities were in line with the aims Melanie discussed when I interviewed her after the performances. For example, one audience member said, “I think it was supposed to give the audience a personal connection to it. Made you think about it beforehand and...umm..saw how it connected to the scene. It was cool.”

### **Using Frontstage to Build Community**

In the last case of Frontstage use, I will examine, Gina, a researcher and expert in risk communication, used the Frontstage system in an ethics training presentation that was part of the National Nanotechnology Infrastructure Network (NNIN) Research Experience for Undergraduates. The weeklong convocation focused primarily on allowing the undergraduates to present their research. Conference organizers also wanted to provide a way for them to begin to think about the societal and ethical issues surrounding nanotechnology and invited Gina to present them. Gina wanted to engage the students in a discussion rather than lecture to them and

decided to use the Frontstage system as a tool to foster this discussion. Her perception was that there was a lack of consistency and, in some cases perhaps rigor when introducing social and ethical issues.

So one goal was to give them consistency about different definitions of ethics and to introduce them to some societal impacts. The bigger goal, and this is truly where the interactivity comes in is to increase their ability to think critically about societal and ethical ideas, impacts, issues. In my mind, the only way to do that is to make them think on their own... My goal was to have them think about their opinions morals values ethical standards about nanotechnology.

Gina initially had two goals in mind: the first, to provide a clear way to think through social and ethical issues, the second, to be able to think critically about these issues. To her, the second goal hinged on her ability to provide opportunities for interaction, and she was not alone; her research into SEI trainings at this level suggested to her that interaction was an important part of fostering the ability to think critically (Eosco, Tallapragada, McComas, & Brady, 2014). These two goals seem to focus more on interpretation than understanding, but seem to be predicated on some level of understanding of material. Gina also discussed a third goal, which fits neither expression nor explanation. She hoped to get the students, who had not had the opportunity to mingle or get to know each other for most of the conference, to interact with one another. This goal became increasingly more important throughout the planning and execution of the presentation.

Because Gina aimed to get the audience to engage in this kind of critical thinking and in conversation with one another, her use of the system was quite different from Holly's and Melanie's. She was less concerned with the potential for inappropriate content or device theft. In

fact, I do not believe the topics even came up in our early discussions. She, her undergraduate research assistant, Merrill, and I met and I demonstrated the system for them. I was relieved that they decided to give the devices to the audience members directly, rather than to work, once again, through an intermediary. But, to my surprise, Gina decided to give the devices to groups rather than individual students. The students (approximately 100) were seated at round tables of up to ten people, and Gina and Merrill gave one or two devices to each table of students so that each group contained four or five students. There were a total of twenty-two groups with a device. Gina said she chose this configuration because she was looking for a new way to accomplish the work in small groups in these kinds of presentations. In her experience, small breakout sessions often result in one person taking notes, and then that person reporting back to the whole group later. To save time and offer a more enjoyable way to get the same end results as traditional group work and “report out” strategies, she decided to use the word cloud to display small group work for discussion.

After a brief introduction to the topic of ethics, she posed a series provocative ethical questions to the students and asked the groups to type their responses into the Frontstage App on their iPods. She first asked the audience if they would put an RFID enabled tracking implant into a senile grandparent to keep them safe, then if they would put the implant into a child, then finally, if the device should be implanted in soldiers to identify them. Their answers for all three parts of this question were entered into a single session, to be displayed on a single Wordcloud (See Figure 16). Gina waited to display the responses until all groups were finished with all three

parts of this question before revealing the Wordcloud generated from their responses. She did so

what's up kids swagbuff here does this work yeah, keeps him safe no if this is allowed then the RFID could be used on other humans tag him informed consent probably wouldn't we tag cats and dogs why not harm tag my son Yes, if he approved. It would be safer for him in the long run, but he should have the right to refuse I'll put gps on the car too tracking yes long term health effects are not a concern

get consent I love my son but I'll shock him if he gets too close to a bar no know where he is consider external device options grey area it would be weird if I was daring someone why does it need to be implanted he may be in danger, so yes. considering only the info given wait until your married consider whether you were tracked he Alzheimer's in ithaca wandered like if tracked through cell phone other options found her four days later and dies of exposure how will RFID affect disease progression swagbuff wants consent from pappa does it hurt him put in clothes in Europe they will tag you voluntarily yes. tag him don't know side effects never mention the implant is removable discuss with father yes, it is for his benefit with no detrimental effects we believe that it would benefit society if we tagged our dad There are easier ways to do the same thing: bracelets, ankle brace etc what if it was free a Florida a boy got tagged by his family how invasive is implantation procedure first talk to him and discuss it, ultimately tag him. the cons of invading his personal life is much lower than the pros of safety our group would tag him why nanotechnology we don't know how biocompatible or safe it is yes, dad is in danger. during a moment of clarity, describe it to him then do it not a complete solution instead put an alarm system pretty undignified way to die yes because you are in charge of his care; he cannot make an informed decision; privacy is superseded by his need for aid on exits assuming the father is told of the device and in support alternative methods not if he's the first patient with this device He has some choice in the matter yes, after telling him why you are doing it (you love him what do you do if you're at work and the tag goes off monitor house rather than why is your 5 year old home alone transition. elementaryvschool If he is incapable of making conscience decisions, then yes should be monitored in e school smart phones if the kids have Alzheimer's, then yes yes. double tag the daughter conspiracy age doesn't matter does the child have Alzheimer's or is it a regular child definitely not an option for kids if they still have Alzheimer's then the answer doesn't change; yes difference between gps and RFID information responsibility for elementary kids privacy intent what is the urpu field of flowers commercial RFID too permanent I wouldn't put that on my child purpose bs intent yes, it may increase lifespan, as long as there are no social complications it already your job to keep tabs on them and not let them wander lifetime impact why does your elementary student have Alzheimer's a matter o time before your injected dehumanized why put off then inevitable tag dad. care for him. not in the proper state of mind to make a roper decision.what are capabilities of the RFID ok if voluntary not the kids. privacy must be given, and it's your job as parents to teach the kids to be responsible and not get lost same as done to dogs not for children. if the information isn't secure, it could be used to kidnap children should spend time with father when I was a kid I didn't get lost the amount of information that is already put out on the Internet family responsibility not really helpful at times annoyed can a young child really give informed consent phone tracking we should take more personal responsibility not for soldiers, that's ridiculous soldiers I don't think the soldiers should be forced to get the RFID personal option for soldier swagbuff would use brcelet for kids shouldn't be a requirement it starts with soldiers if the soldiers consented and if it were removed when they Reuters no way to completely secure potential for abuse by other persons/ organizations returned what's the difference between a dog tag and the RFID terrorist hackin the system can be hacked by outside countries and all of out soldiers can die opt in no, too many security concerns. if the enemy finds the codes they would all be killed we all got vaccines without consent possibility of abuse could it be removed later people can take advantage of this to track people mention the tag in a reasonable, informative manner in all cases can't turn it off we would be very hesitant in implanting a RFID tag. we understand that we need to track dad and the children, but there are other options RFID have limited range could threaten soldiers if someone figures out RFID too much overwatch yes for overseas deployment it's the soldiers' decisions No even though they are soldiers they still have basic rights. Also, could this technology be accessed my terrorists no because afraid of interception of signal what color are we swagbuff says absolutely no tagging soldiers since it is dangerous to the swagbuff soldiers are govt property so sure 78==Dad's age make all RFID applications an area of informed consent swagbuff concerned about soldier morale

**FIGURE 16: The Wordcloud created by Gina's prompts questioning whether students would implant an RFID chip into an elderly grandparent, a child, or a soldier. The text has been shrunk so that the entire word cloud fits into a single image. During the actual presentation, the text was much larger, and Gina could not show the cloud in its entirety, but had to scroll through from top to bottom.**

to an audible response from the students, most of whom seemed impressed and excited by the Wordcloud. We heard students mumble things like “cool” and “oh wow!” Like the answers provided by the elicited by cast members and provided by audience members in *Long Ago in May*, most of the answers were longer phrases, unlikely to be duplicated, and so they formed a long, scrolling stream of consciousness-style series of responses.

Gina's second question asked students if they would allow their teenage daughter to wear a bracelet that tracked all of her purchases if she was paid to do so. For this question she displayed the word cloud as it was being generated (See Figure 17). During the second question, if an audience member liked an answer they saw on the display, they would retype that answer to make it larger. For example, the largest phrase was, "how much money" which was followed by simply, "no," and "it's a trap" and "honey badger dont care" [sic]. These last two phrases were both pop culture references that the students found amusing. While the amount of silly, off topic, or inappropriate comments increased during the second cloud, there were also some off topic phrases in the first cloud. Particularly, there was a student who announced her or his persona, "Swagbuff is here" and continued to input phrases that, while they were on topic, were phrased in terms of this person. The second cloud may have featured more inappropriate content because it was visible as it was being populated, or because students had become more comfortable and free to express themselves. I suspect that, coupled with the knowledge that they could impact the size of each phrase, the latter had a larger impact on their behavior. These mischievous remarks were the subject of giggles amongst the student audience. In Gina's opinion they did not detract from the overall presentation, but rather, helped the audience to connect with one another, which was something they had not been able to do during the rest of the conference.

As I observed the ways the groups used the iPods during the initial task of answering the ethical dilemmas, I noted that though some groups actively discussed what they wanted to enter into the word cloud, sometimes the small groups chose not to actively discuss ideas and accept or reject them as a group, but rather, the person holding the device simply entered everything group

don't care manual labor privacy hell no straight up is how you raise a child that's not an idiot impartial **no** could  
 be Mexico opt out prelude to other tracking she wants to what a 14 yeah old need money for what does she need  
 money for at 14 can she stop at any time no tech mention **honey badger dont care** easy  
 way to make money future invasion of privacy research the company first her choice our group does not support child  
 labor or human traffickin sure I would let her do it but I wouldn't look at her bank account surrender to your google  
 overlords how is this different than online ad personalization **yes** only sixteen or older swagbuff says nah cuz daddy  
 issues if she agrees **how much money** understand first she has control  
 bribery hackers minority report tech **honey badger don't care** media targeting **thugbuff > swag**  
**buff** live tracking badger don't care surrender don't parents already know what she buys already do it for free  
 surrender to your google overlords anonymous no big brother stuff wait til she's 18==Done deal this is an example of  
 tr destruction of society through the unrestrained expansion of commercialism children shouldn't have money let her  
 know daddy and mommy and IBM is going to see every single step she makes why bribe parents parent shouldn't have  
 monetary incentive don't know what the money is used for no information could be accessed for nefarious purposes. ok  
 if 18 pyramid scheme **NO** nope just extended media tracking and targeting I hate pyramid schemes. sketchiness I'm  
 cynical does it come in fashionable colors **it's a trap money** worth it for coupons swagbuff don't need  
 no charity no real change i did not ask for that....so no **money money money money money**  
 depends on person and if they want their purchases shared only if I can pull out whenever no don't know who else is  
 watching or final use same concept as telemarketing pay in cash leave no paper trail no, she is too young to make a  
 decision about privacy sucks to suck down with the flags of capitalism and materialist society it's all corporate  
 manipulation they give you more money to spend on more products. it's. never ending cycle #mindblown **SWAGBUFF**  
 can u take the bracelet of given very thorough examination of company's interests and reasonable autonomy of child,  
 we're cool everyone hates telemarketers money money money I just have a lot of feelings one concern is that people  
 with less money would have to give up there privacy while people who are rich won't have to give up their privacy I  
 would, coupons <3 **is whoring out your daughter ok** pimpin ain't easy swagbuff > thugbuff > honey  
 badger hi 58

**FIGURE 17: The Wordcloud created by the students during the second ethical dilemma Gina presented. During this exercise, she displayed the word cloud from the beginning, allowing the audience to “vote up” entries they liked by duplicating them.**

members said. Sometimes the person with the device typed their own ideas before asking for more ideas from the group.

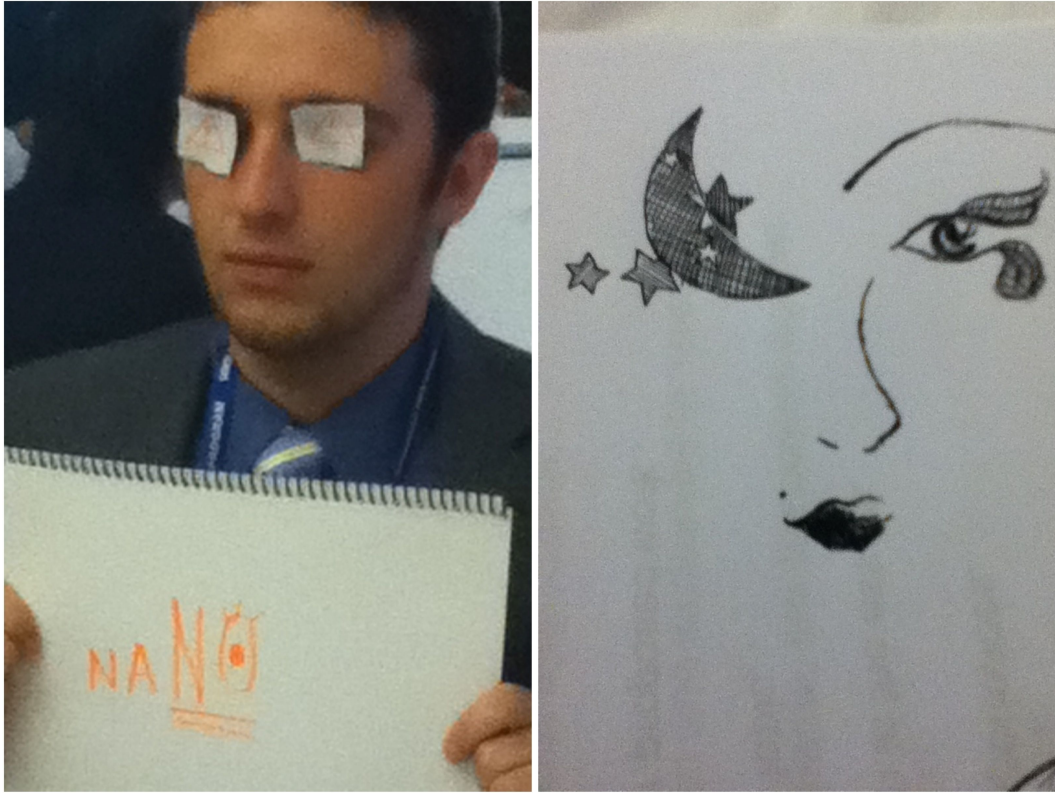
For their last group activity, Gina had the groups use the Photoview module. The activity was meant to help them think creatively about different messages and motives in commercial uses of nanotechnology. She had the students brainstorm and come up with ideas surrounding a new kind of contact lenses made using recent advances in nanotechnology. She divided the room in half and had the groups on one side take the role of a public advocacy group and develop a public health campaign warning of the dangers of these contacts, while the other side took the role of the company making the contacts to develop an advertising campaign promoting them. Each group was to devise a visual and a slogan for their respective campaigns, using Photoview

to take a picture of the visual they created and the Wordcloud to enter their slogan. Some took photos of drawings they made while others created tableaus and took photos of members of the group. She then displayed the images and, one at a time, went through them and asked the teams who submitted them to explain them and to read their slogan aloud (See Figure 18 for two examples of photos taken by teams).

The dynamics of the small groups were different during the campaign exercise. Because they could only submit one photo and one slogan, they spent quite a bit more time discussing, generating ideas, and generally interacting with one another, as opposed to the ethical dilemmas, in which the unspoken rules seemed to be similar to those in the early stages of brainstorming: no ideas are bad, let's type in everything everyone says. While the first exercise may not have generated in depth discussion among the small groups, I believe there may have been a benefit to the attitude that any ideas are welcome, and I wonder if it may have helped them to engage in the discussion necessary to develop the campaigns during the second exercise.

After both the ethical dilemmas and the campaign exercise, Gina used the Wordcloud and Photoview images generated by the questions to facilitate a larger discussion among the whole group. During the ethical dilemmas exercises, the discussion was fairly loosely structured. Gina picked out specific answers from the cloud and opened up dialogue about them. For example, several of the Wordcloud comments from the first ethical dilemma suggested the person implanting the device should obtain consent from the person being implanted. Gina asked if someone with Alzheimer's could realistically give consent. Other comments questioned the safety of the technology and Gina put the question to the whole group. The group answered,





***FIGURE 18: The image on the left was from the group asked to come up with a campaign to warn of the dangers of the new technology, while the image on the right was from the group asked to develop an advertising campaign for the lenses.***

collectively, that the safety could not be known, and Gina replied that it was important to note that a room full of scientists could not accurately assess the safety of new technology.

There were three different kinds of group work happening during this presentation. The first, the responses to the ethical dilemmas, is best likened to the beginning stages of brainstorming, and allowed most participants to share their ideas. As the students themselves noted, the Frontstage app made it easier for shy students or students who were not particularly passionate about the topic to participate. So these prompts helped the students become better acquainted with each other, and with this dynamic of brainstorming. The second kind of group work, the small group campaign prompts, allowed them to work together as small teams, and the third kind, the large

discussion among all of the audience members provided a way for students to put their own views and ideas in context, and to glimpse the diversity of opinions on ethical issues. For Gina, Frontstage was novel because it afforded a combination of these forms of group work, and easy transition to full group discussions:

I think using the Frontstage app offered a different way of sharing interactivity. That each group in and of itself got to create their own word cloud or in and of itself got to create their own photo. So they were interacting together in a small group, but the app, through the iPad software, allowed the group to share those interactive experiences as a large plenary group. And that's really hard to do. When I've done presentations in the past, yeah sure we've done breakout groups, but you have to have a secretary someone has to take notes, and then you have to take a long time to have each group report out because of course I want every group to know your comments are important to me. But you know when you only have an hour and fifteen minutes and you've got a hundred people in the audience you don't really have a lot of time to do that. And I think that the app really allowed shared interactivity. Shared interactive experiences, I guess, is what I'd call it.

This idea of shared interactivity speaks to the way Gina envisioned the app helping foster communication among the students. Though this goal seemed at first to be secondary, it became more and more apparent that Gina felt there was a benefit to helping the students connect with one another. She explained that they had watched each other present all week, but had not been able to really interact, and, subsequently, had not really been open to speaking with people who were not from their own schools. While this goal may not seem to have much to do with the goals of building basic competency in thinking about ethics or fostering critical thinking, Gina

was more broadly concerned with their group dynamics as a potential step in toward collaboratively thinking through ethical issues, something she hoped she could help foster in the scientific community.

Though I was able to gain rich insights from my observations of the group work and use of Frontstage by audience members during Gina's presentation, I once again found it difficult to find a way to directly question the audience members about their experiences. In this case, the timing of the conference was such that they did not have breaks between activities; however the next activity was lunch. I ended up approaching tables of students while they ate to ask them about their participation in the presentation and their use of Frontstage. Like other audience members, the students kept their answers, for the most part, brief. Most of them felt that Frontstage made for a more fun and interesting experience, and many noted that Wordcloud allowed more members of the audience to voice opinions. There were a few reasons given for this: First, the students didn't feel they needed to reach consensus in their small groups, instead, they were able to type in all of group members' opinions. Second, they did not have to raise their hands or speak aloud, which meant audience members who were less passionate were still able to be involved. And finally, the anonymity made it easier for those who may had been uncomfortable speaking in front of the large group to still have their opinions heard. This anonymity was also likely one of the reasons for the inappropriate or off topic interjections in the Wordcloud, which had been a concern for both Melanie and the production team and Holly and her colleagues. As I suggested above, Gina was not concerned about these remarks, and, in fact, thought they were helpful in building a sense of camaraderie amongst the students. When I asked

the students, their responses were mixed. Some felt that they were a fun way to break the ice, but others found them to be distracting.

### **Learning From Frontstage**

These presenters incorporated the Frontstage system into their events in very different ways. While all of them thoughtfully planned their interactions with audiences, the production team and performers of *Long Ago in May* spent quite a bit more time than the rest, focusing not only on what kind of content they wanted to use for the interaction, but also on the aesthetic experience. The designers had concerns ranging from color scheme to lighting the set and audience. Meanwhile, other presenters, both in the early tests at the cafe and at the museum and conference, did not comment on the aesthetic qualities of the system. This may seem obvious, but it merits pointing out that the production team was highly attentive to the audience's overall experience, while the other presenters seemed more concerned with the specific content of the interaction. These genre differences reinforce the subtle ways scientists and artists differ when they consider audience participation. Though it is not the same tension Maren and Itai faced when they were negotiating over explanation and expression, it seems related. The experience itself was meant to be aesthetic, and thus, the aesthetic was at stake for the production team, whereas, in the other cases, the experiences did not possess the same kind of aesthetic value.

### **Trust**

Perhaps the most revealing aspect of observing presenters as they used the Frontstage system, regardless of their field, was watching presenters struggle with how much trust they had in their audiences. The prospect of giving a device to the audience and trusting them to give it back was

too daunting for Holly and her colleagues and for Melanie and the *Long Ago in May* production team. The trust issues, however, went beyond this initial hurdle, which was manufactured by the fact that we supplied the devices rather than having audience members download the application to their own phones. There was also a mixture of fears concerning audience members' abilities to refrain from providing inappropriate content and a mistrust of their ability to use the devices and to engage responsibly and responsively in the way the presenters wanted. For the creators of *Long Ago in May*, it seemed that there was a strong resistance to allowing the audience to play a role in shaping the performance. Their decisions to ask audience members to recite their feelings and thoughts on love to actors who faithfully typed them into the Wordcloud, and then displaying the cloud, the producers of Frontstage provided a way for audiences to express themselves without ceding authority over the aesthetic quality of the show. This form of boundary work served to protect the authority of the production team.

The use of intermediaries (either volunteers at the museum or actors at the performance) was born from this drive to protect authority; however, these brief encounters changed the nature of these events. In both of these cases, the intimacy of a personal conversation struck a different tone than a presentation normally would. While this was followed by a presentation in *Long Ago in May*, at the museum this was the only encounter with authority figures at the museum.

Volunteers or actors and audience members forged unique relationships through these conversations. These volunteers served as their total interaction with Frontstage. In the case of *Long Ago in May*, actors noted that their interactions changed the nature of the performance either by diminishing the mystery or by putting them at ease. Volunteers or actors and audience members forged unique relationships through these conversations.

When trust was extended, and to some degree, abused, as it was when Gina's students entered inappropriate content into the Wordcloud, Gina felt the sense of camaraderie that was built through the jokes had value, even if the off topic remarks detracted from the conversation. Though some audience members found the jokes distracting—and some of them were completely off topic—many were humorous ways of engaging with the questions Gina posed. Beyond the camaraderie and the witty delivery of relevant opinions, it was clear that the audience recognized the trust that had been placed in them and felt empowered to either participate as Gina asked, or to redefine the experience by participating in unsanctioned ways.

### **Expression, Explanation, and the Audience**

As I suggested earlier in this chapter, the expression invites interpretation on the part of audience members, and constrained expression in the form of explanation seems to invite understanding on the part of the audience. But this is not to say that the relationship between interpretation and understanding is identical to the relationship between expression and explanation. Nor is it to say that audiences interpret or understand while presenters express and explain. The participatory experiences created using Frontstage asked audiences to interpret and make comments on what and how they were interpreting, but, as in Holly's questions about the web of life, they occasionally asked audiences to express themselves and to interpret one another.

Thus far, I have written a great deal about expression and explanation, focusing on how expressions can be constrained by presenters so that they can guide the way audiences interpret texts. But I have not given the same consideration to what I mean by interpretation because the

discussions have been so focused on the presenters. When audiences interpret something, they make meaning out of it. As Hall would suggest, audience members decode messages or texts.

Before this message can have an ‘effect’ (however defined), satisfy a ‘need’ or be put to a ‘use’, it must first be appropriated as a meaningful discourse and be meaningfully decoded. It is this set of decoded meanings which ‘have an effect’, influence, entertain, instruct or persuade, with very complex perceptual, cognitive, emotional, ideological or behavioural consequences. (Hall, 2000, p. 168)

Hall goes on to describe several ways of decoding the meaning of texts: dominant, negotiated, or oppositional. While there is a much greater variety in the ways people interpret texts than a loose reading of Hall might suggest<sup>28</sup>, and a much greater variety in the ways presenters encode them than just for dominant meaning, the point Hall makes is that audiences have the right to make their own meaning from a presentation no matter what the presenters intend. So, constrained expressions need not be interpreted in the exact way the constraints call for. Interpretation, then, might mean actively seeking one’s own meaning from a text. Alternately, understanding an expression might mean working to find the encoded meaning rather than freely interpreting meaning for one’s self.

For Frontstage, presenters sought a wide variety of interpretive activities from their audiences.

Gina constrained her expression so that the conversation would turn toward ethics. She invited

interpretation of the ethical scenarios she presented, but then also asked for expression of

personal thoughts and feelings surrounding that interpretation. These small group and individual

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<sup>28</sup> Hall notes that these three categories are not discrete, but rather, a part of a continuum. Still a continuum (a line) is far different from, for example, a plane, in which possible ways of interpreting or decoding a text may fall not along a continuum from dominant to oppositional, but also orthogonal or any other relationship to the constrained expression.

expressions were then interpreted by the group in a larger context, so the relationships were not just between presenter and audience, but between audience and audience. Holly asked for interpretations of themes like biodiversity and nature, but did not focus on sharing those interpretations with other audience members, neither did she focus on evaluating or assessing them. The priority for Holly was to provoke expression and interpretation within an individual, giving them an opportunity for reflection. For her, the primary goal was to connect audiences to themselves. Melanie hoped to provoke audiences to think about and express their feelings about love before the performance. During the process, she either intentionally or inadvertently created an opportunity for a more intimate conversation between the actors and audience members, allowing audience members to express their ideas and actors to interpret those ideas. During the performance, when the audience members' words scrolled across the stage, they were introduced to one another's expressions, much the way Gina's audiences were during her presentation. In addition, she was asking audiences to interpret the play itself, which was a fairly unconstrained expression. The lack of narrative, broad theme of love, and experimental style provoked audiences to interpret the love theme, incorporating their interactions before the show, the text of the performance, and the words of their fellow audience members.

These relationships between and among the audience, the presenters, and the text (when there was a traditional text) were much more fluid than suggested by both Hall, with his continuum from dominant to oppositional, or by science communication scholars, who focus on up- or downstream communication. These relationships are even more fluid than Peters' conception of dialogue and dissemination, as both constrained and unconstrained expression could be present in one presentation, and expression could be constrained in an infinite variety of ways to



different degrees. I would suggest that most of the descriptions I take issue with use the metaphor of a road that can go in two directions, but that a more apt metaphor would be a field akin to what Peters describes when he discusses dissemination as a sewing of seeds.

I would like to end this chapter by returning to the questions I had when I began: Can the twin goals of engagement and assessment be accomplished at once? How do presenters make decisions about how to use audience participation? Are they thinking of specific assessment or engagement goals? How are they defining engagement or assessment? Are they even thinking in terms of engagement or assessment? Based on the experiences I describe above, I would like to reframe these questions, which seem to be predicated on a kind of continuum of their own, so that they, too, can be answered using the metaphor of a field. Rather than seeking opportunities for assessment or engagement, which don't seem to be very specific, I would suggest that presenters are seeking opportunities to express, but also opportunities for the audiences to express in any number of more or less constrained ways, and that they seek opportunities for audiences to interpret their initial expressions (the text plus the constraints they wished to place on those expressions), but also for audience members to interpret or understand one another's and their own expressions, and opportunities to interpret and understand audience expressions themselves. Describing presenter aims in this way is far more descriptive and flexible than my original language of assessment and engagement.

## PART III

### CHAPTER 7: CONCLUSION

In the Chapter 4, I examined *Dance of Scales*, a performance created by a physicist and a choreographer. This chapter examined the collaborative process, which, while largely amicable, contained some degree of friction because Maren, the choreographer, aimed to openly express something to be interpreted by audiences, while Itai, the scientist, aimed to explain his ideas to the audience, to be understood as closely as possible to the way he understood them. This difference between expression and explanation may, at first glance, fall into the typical patterns of art/science collaboration problems, like the tendency for one to be in service of the other. However, it was not necessarily that Maren and Itai wanted their work in the spotlight, drawing on the other for support; it was that there did not seem to be a way for her to invite open expression at the same time he was attempting to explain his ideas. The two seemed to be incommensurable.

This consideration of expression and explanation caused me to reconsider traditional thinking about dissemination and dialogue. Dissemination, as Peters (2000) describes it, is like the sowing of seeds. Audiences are free to interpret disseminated messages, while those involved in dialogue must come to some kind of agreement of meaning. I found that contrary to engagement literatures, dissemination, like Maren's form of expression, provides opportunities for open interpretation, while dialogue, much like Itai's explanation, begs for a meeting of minds in which both sides of a dialogue come to the same conclusions. In situations in which power is not

balanced, this kind of meeting can resemble deficit model thinking much more than dissemination, which is so often associated with the deficit model.

*Emergence*, the subject of Chapter 5, focused on another art/science collaboration that was not as clear cut as *Dance of Scales*. In *Emergence*, rather than a conflict between open expression and explanation, several different sets of constraints were at odds to some degree. The choice of narrative realism as a style for the play itself was one form of constraint, while the epistemological realism that drove Itai's desire to explain his scientific concepts drove another set of constraints, and finally, the development of easy to follow rules audiences would be willing to follow formed a third set of constraints. These sets of constraints were ways to shape the audiences' interpretation of the text, and while there was much overlap between them, there were times when they were at odds. I proposed constraints can come in many forms, across an all but infinite field of possibilities. Explanation is one kind of constraint, and realism, or realisms, are another.

These different ways of imposing constraints called into question Hall's continuum of decoding, or interpreting meaning from texts. He suggested audiences can decode meanings according to the dominant message (or expression), they can take a negotiated meaning of the text, or they can take an oppositional meaning. This continuum seems to be predicated on the idea that there is but one meaning encoded into a text. In *Emergence*, there were several, each manifesting itself in one of the ways the expression was constrained. Additionally, audience members might Just as an expression can be constrained in a multitude of ways, it can be interpreted in just as many ways, not just according to the dominant meaning or in negotiation or opposition to it.

The sustained interest in audience participation among artists and scientists like those who participated in *Dance of Scales* and *Emergence*, coupled with my work with cultural probes and interaction design prompted me to further examine audiences and participation in Chapter 6. The Frontstage system was a research through design project that used a design problem—building an audience participation system—to open up and explore a complex set of research questions about how presenters conceptualize their relationships with audiences and what they aim to do for and with their audiences. Once again expression and constrained expression were part of my analysis of the use of Frontstage. I witnessed the designation of a theme, mood, or emotion, as a way of creating loosely constrained expressions. These expressions were meant to be interpreted more openly than, for example, explanation, but were ways of guiding audiences to think about specific themes.

Having focused on expression in Chapters 4 and 5, in Chapter 6 I turned to an examination of interpretation and understanding as the goals of expression and explanation. While interpretation and understanding are not exact analogs for expression, it was useful to think of understanding as possessing qualities of interpretation. Just as all explanation can be understood as a subset of expression, all understanding is, on some level, a type of interpretation, one constrained by the attempt to come as close to the exact meaning conveyed in the explanation as possible.

Understanding always involves some level of interpretation because no two minds can ever really possess the exact same knowledge. But, the relationship between interpretation and understanding is more complex than that. Understanding, that is, an effort to comprehend constrained expressions as their creators intended, can lead to interpretation. Such a relationship occurred in several of the cases described in this dissertation, though it is difficult to pinpoint in

the Frontstage cases because there was something else happening in most of these cases that complicated the relationship between expression and interpretation. Frontstage cases revealed instances in which audiences were asked not to interpret or understand, but to express their own ideas. Most often, this was done within the context of the expression the creators presented, so audiences were asked to create expressions through their interpretation or understanding of expressions created by the presenters. In some ways, interpretation and understanding can be seen as an analogue to the relationship between expression and explanation. But there is also an interaction between expression/explanation and interpretation/understanding that complicates the analogy. Additionally, understanding is a bit more general and universal than explanation as I use it here. Understanding is an attempt to interpret a constrained expression as it is intended, whether that constraint can be described as explanation or not. Audiences might attempt to understand a narrative story, which might not be called explanation, but would certainly be a constrained expression.

### **Expression, Explanation, Interpretation, and Understanding**

Thus far, I have discussed the relationships between expression, explanation, interpretation, and understanding in terms of each specific case. A broader discussion of these relationships is needed to make sense of how they relate to the broader experiences of presenters and audiences and of artists and scientists. The thread that runs through these three case studies begins with the difference between expression and explanation, but soon progresses to a more nuanced consideration of the ways expression can be constrained, and finally turns to interpretation and

understanding. To clarify the relationships, I will begin with expression again, focusing on expression and interpretation.

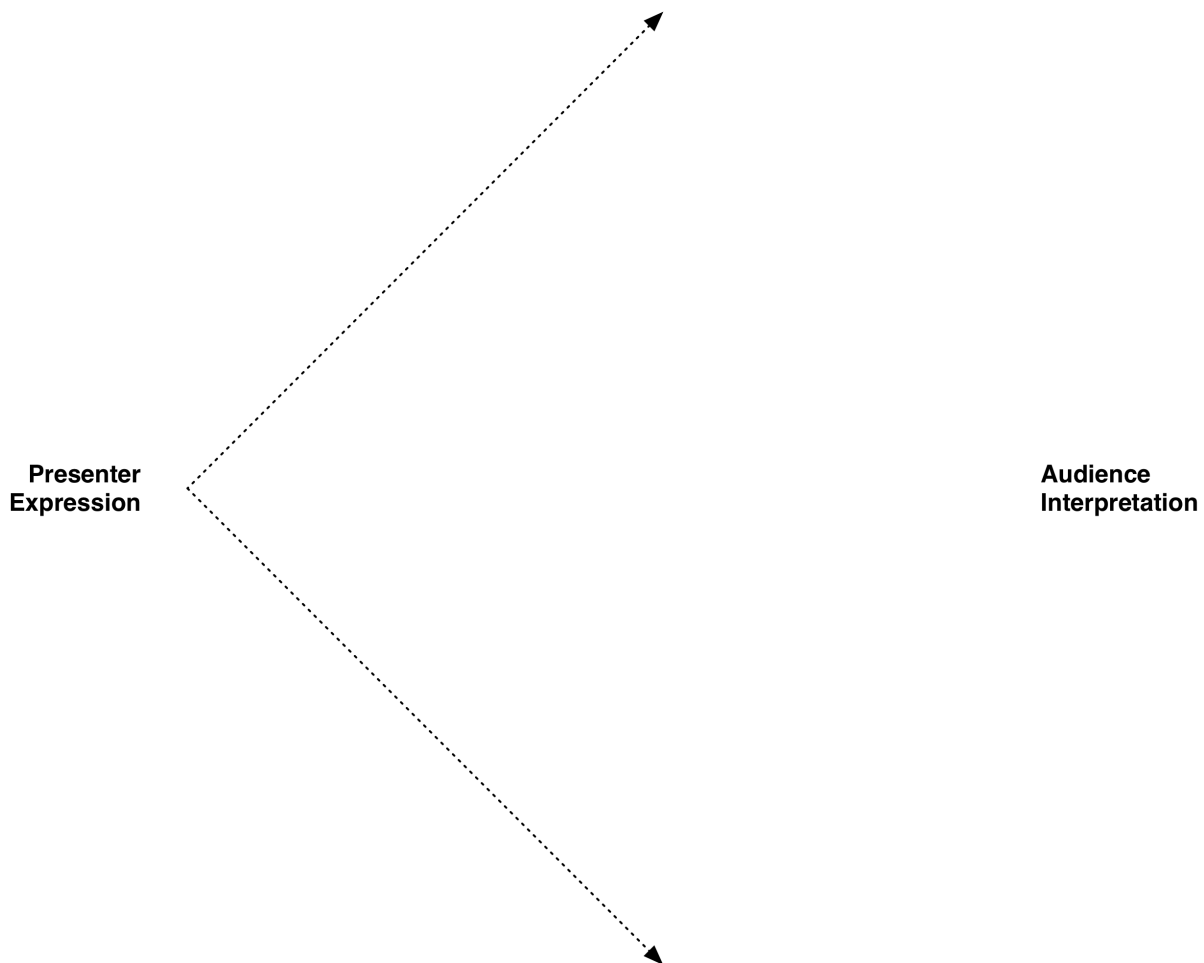
### **Expression and Interpretation**

Expression, I suggested, is what a presenter does when they create a text for an audience; they are creating forms of expression. In Figure 19, I represent expression as a field emanating from the presenter or creator and the text. When an audience member engages with the text and makes their own meaning from it, they interpret the text. While what Hall calls encoding might resemble interpreting, expression is more than what he calls encoding. Expression comprises text as well as the encoded meanings, while interpretation is the meaning as decoded by the audience member. When presenters place constraints on those expressions, they attempt to specify the ways audiences interpret them.

### **Expression and Explanation; Understanding and Interpretation**

I suggested that explanation was a constrained form of expression. When presenters seek to explain their ideas to audiences, their hope is that audiences will understand them. Explanation and understanding, like Peters' description of dialogue, are the components of an attempt to create circumstances in which the presenter and the audience share the same knowledge in the same way. Visually, this might look like the diagram in Figure 20, in which explanation is depicted as a contained subsection of an open field of expression and understanding is a subset of interpretation. Though Figure 20 might be an example of what presenters envision happening when they attempt to constrain expression as explanation, the relationship between interpretation and understanding might not look like the exact corollary to the relationship between expression

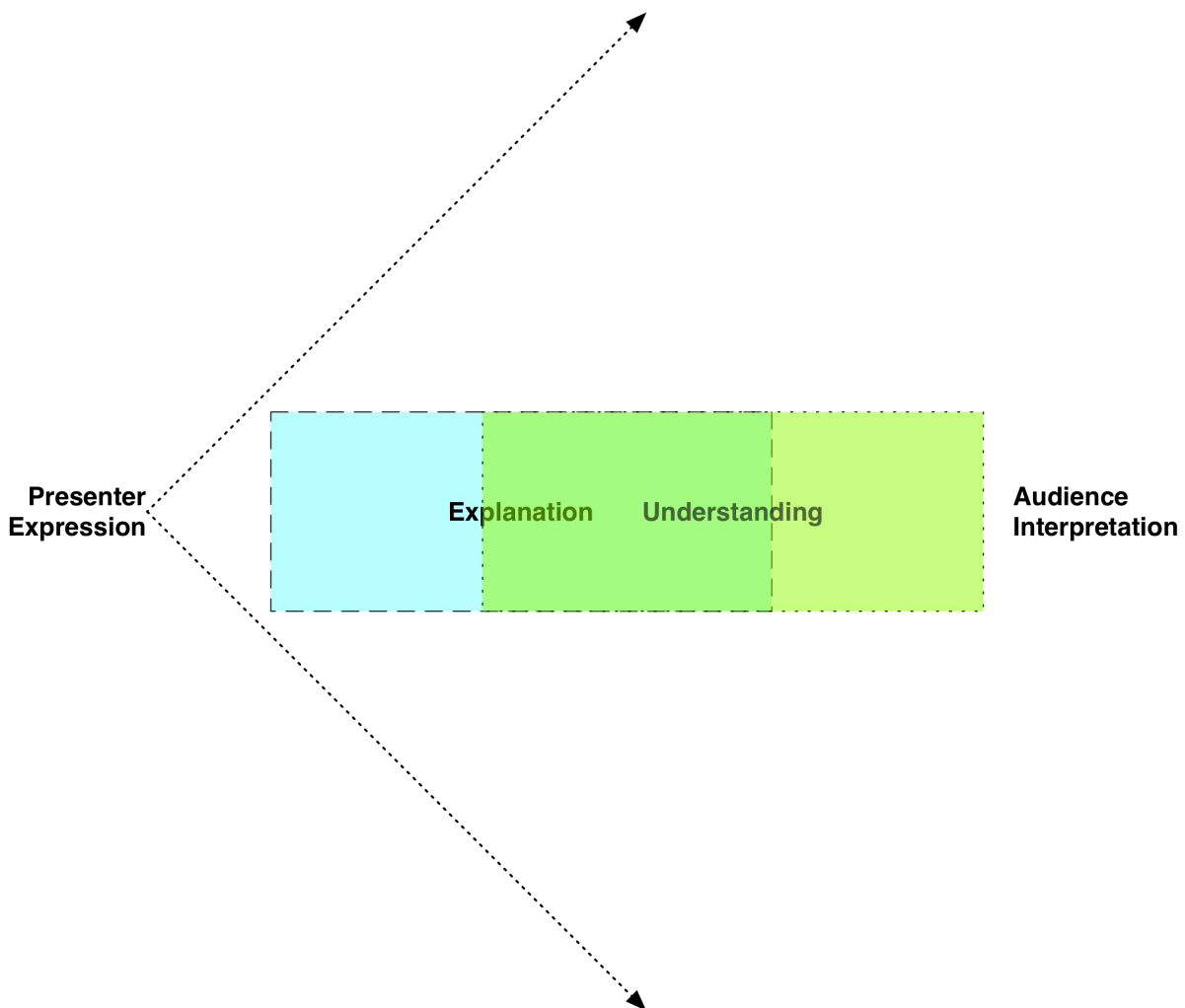
and explanation. Understanding may also lead to more open forms of interpretation. For example, in *Emergence*, when audience members understood Itai's ideas or Aoise's story, or both, they were able to comprehend the performance and to make greater meaning of what they had seen. Audience members drew parallels between their lives and Amanda's; they found profound metaphors for human interaction within Itai's ideas about emergent phenomena. These interpretations were only possible because of the explanation and understanding that occurred,



**FIGURE 19:** *Expression is shown as a field emanating from the creator and text. Interpretation begins as an open space, each audience member can make meaning of an expression how they choose. When creators constrain their expressions, they attempt to focus audience members' interpretations.*

but they were not encoded into the text. That is to say, they were not part of the original expression.

Additionally, explanation is not a perfect way to describe the ways presenters place constraints on their expressions. It is but one way of categorizing the constraints that can be embedded into an expression. In *Emergence*, I found that explanation was not specific enough to adequately

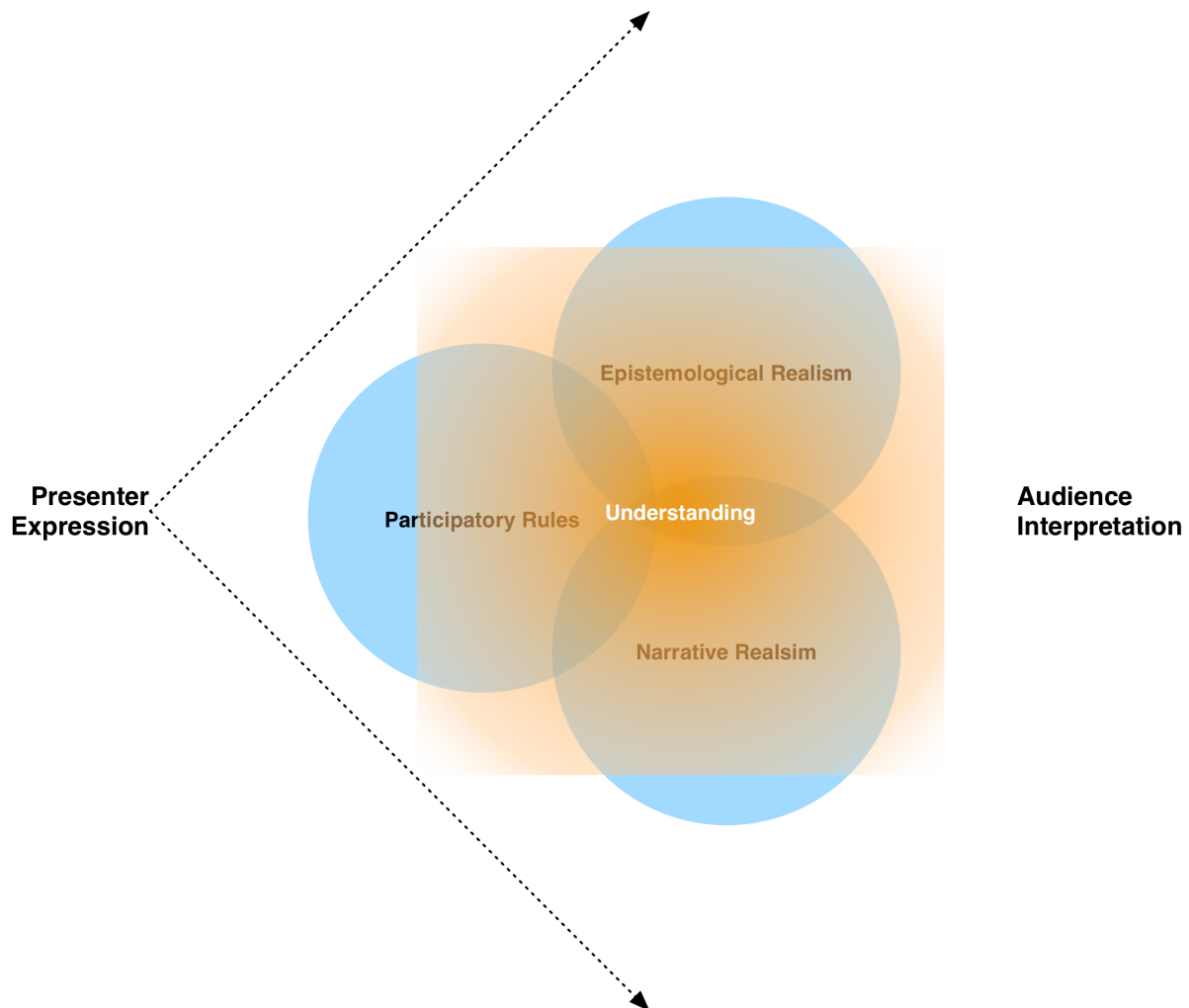


**FIGURE 20:** *Explanation is a specific kind of constraint placed upon expression so that audiences might interpret it in the way the presenter prescribes. Understanding may be seen as a corollary of explanation in terms of interpretation, so that understanding is a way of attempting to interpret an explanation exactly as it is presented.*



describe the ways Aoise's set of constraints, Itai's set of constraints, and the constraints inherent in audience participation were working with and against each other. In Figure 21, I attempt to map the kinds of constraints present in the expressions developed during *Emergence*.

Explanation might be part of narrative realism, epistemological realism, and audience participations, but they each have their own logics; they are each subject to their own set of constraining rules. If explanation was shown in Figure 21, it might intersect Participatory Rules,

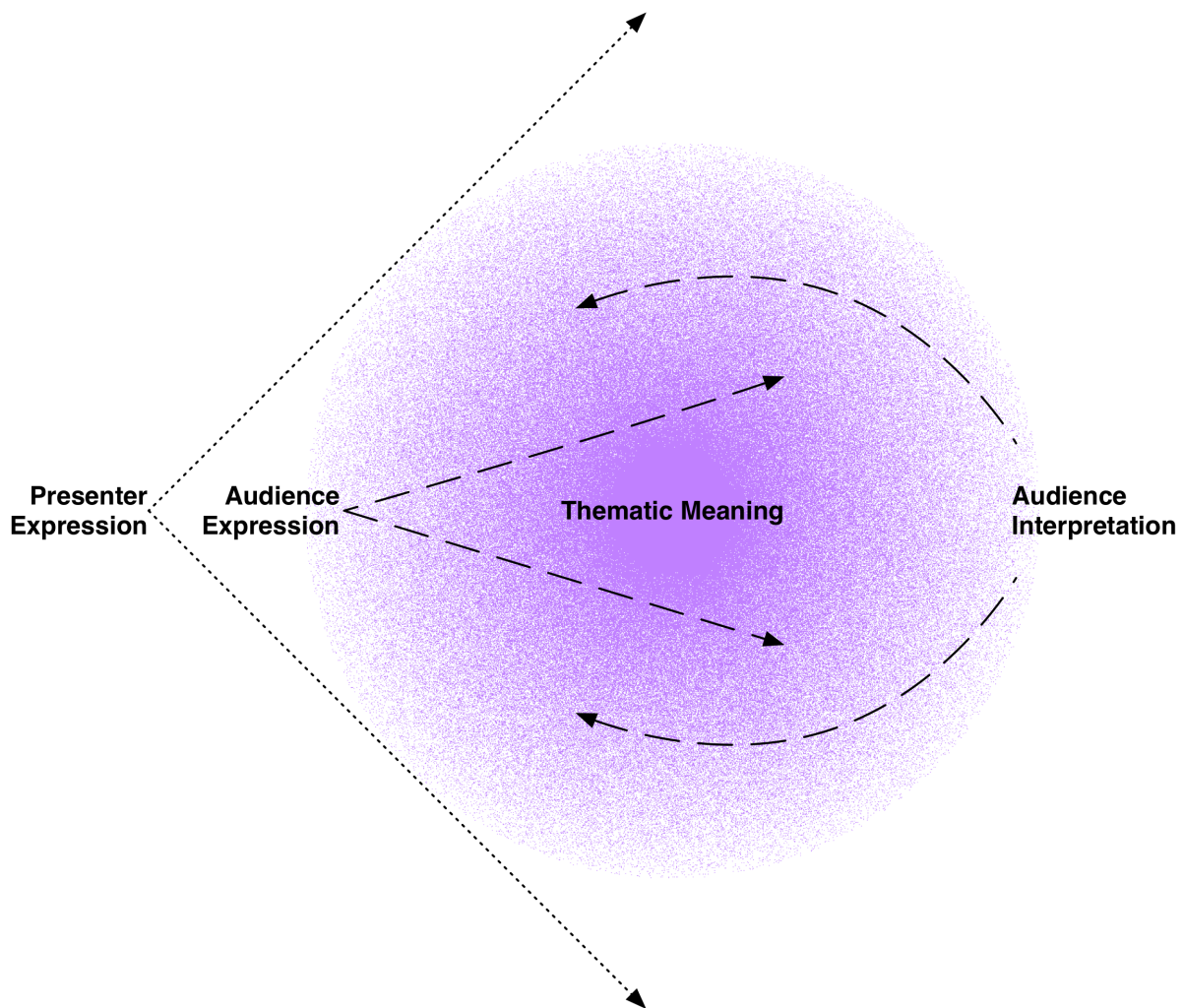


**FIGURE 21:** *Explanation is not specific enough when describing multiple ways expressions can be constrained. This example, taken from Emergence, shows the three different sets of constraints placed upon the expression we created. It also shows audience members' potential understandings and how they might be related to their interpretations.*

Epistemological Realism, and Narrative Realism, but would not identically match

Understanding. Similarly, understanding is not reserved for communicating science, or epistemic knowledge. Aoise's work to express something about the world we created and about the characters was the basis of her narrative realism. The world she wanted the audience to see was far more specific and guided than Maren's description of her work as movement open for interpretation.

In my experiences with Frontstage, I found neither the constrained expressions created by the *Emergence* team nor the open, unencumbered interpretation sought by Maren in *Dance of Scales*. Instead, I found something in between. Some presenters were eager to establish boundaries within which they wished audiences to think and respond. They created what I might call expressive themes and asked audiences not only to interpret these themes, but also to express their own ideas about them, to be interpreted by other audience members. In Figure 22, I attempt to capture the way expression was constrained but open, and the way presenters attempted to share the job of expression and the job of interpretation with their audiences. Thus we have yet another way of thinking about the constraints put on expression, as well as the relationship between presenter and audience, especially when audiences are asked to express themselves as well. If I were to attempt to visualize a more generic view of the relationship between audience and presenter through expression, it might look like a field in which any number of ways of constraining expression would be possible. I envision this field to look something like Figure 23. Some constraints might be diffuse, others clear and sharp. Some might overlap others, some might be transparent, others opaque. Each of these different sets of constraints would shape possible interpretations, and some, indicated by defined boundaries, like the circle with double



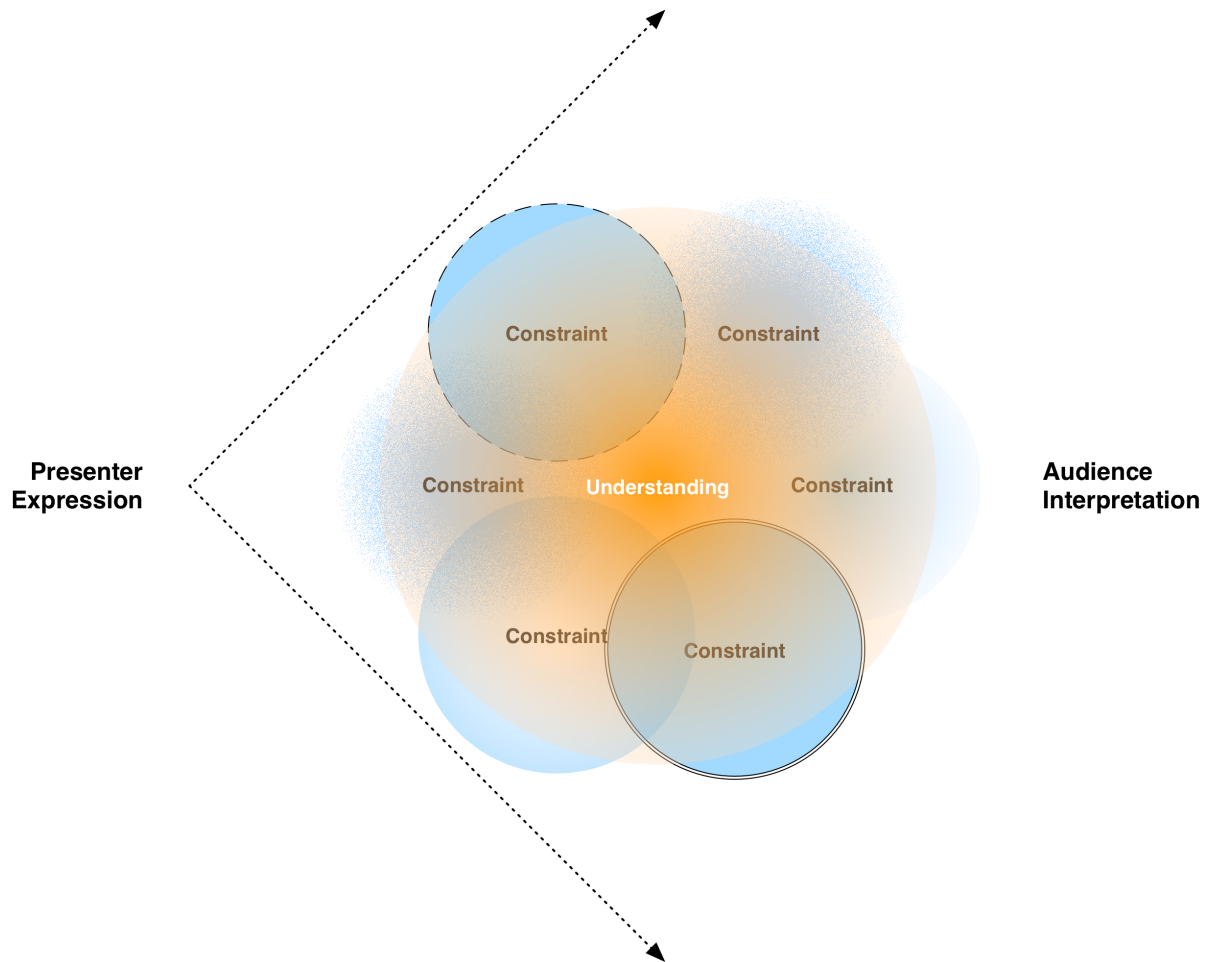
**FIGURE 22:** *The constraints placed on interpretations and expressions in the uses of Frontstage often focused on themes, like love, ethics, and nature. Audience members were sometimes asked to interpret and other times asked to express meaning about these themes.*

lines around it, would aim to tightly control interpretation, while others, indicated with diffuse boundaries, would aim to loosely suggest ideas for interpretation.

### **The Failure of Engagement**

In light of the descriptions of expression and interpretation above, and of the ways potential constraints can impact the experience of both the presenter and the audience, I find I must add

my voice to the growing body of critique of the engagement model. But I will go one step further, and suggest that it is time to admit defeat. Scholars and practitioners alike have tried to make a flawed model work for too long; both engagement as exchange and engagement as interaction have fallen short in their aims to help practitioners develop science communication projects and to help scholars write accurately about what practitioners are doing and how it is being taken up by audiences. They have fallen short for two reasons. First, especially in the engagement as exchange paradigm, scholars and practitioners focused too narrowly on explanation and understanding. Perhaps the most enlightening lesson from *Dance of Scales* and



**FIGURE 23:** *The field of expression may contain many kinds of constraints, each of which make up the understanding and play a role in shaping the interpretation of an expression.*

*Emergence* has been the richness of human expressions and interpretations. Explanation and understanding are but one part of successful science communication endeavors. The relationships described in this dissertation indicate a richer, more diverse set of interactions between practitioners, texts, and audiences than the simple up- and downstream continuum described in engagement literatures. Put simply, science communication is not a narrow stream that flows in two directions, but an open field that can be explored in many directions at once, depending on who is doing the exploring. The second reason the two conceptions of engagement fall short is the primary reason they have been a source of frustration for practitioners and scholars alike. As many of the critics discussed in Chapter 2 note, engagement has become a highly idealized version of science communication and of informal science learning that is, in most cases, simply not attainable given the current power structures within which science and publics operate.

Open expressions make way for pure individual interpretations, and constrained expressions, like explanation, can either impede or enhance interpretation. In some instances, fostering closed expressions lead to a kind of understanding in which audiences are asked simply to match their understanding with the intended explanation. In other instances, constrained expressions ask audiences to understand the expressions in particular ways so that they can then interpret their own meaning with a set of tools or guides that stimulate them to think in new ways. Current and historical models for science communication do not seem to make space for the kinds of opportunities present when constrained expressions lead to understanding that enriches interpretation. Deficit and public understanding models emphasize the importance of tightly constrained expressions that would help audiences only to understand the specific meaning

intended by scientists and science communicators, while engagement proponents often dismiss attempts to tightly constrain expression as oppressive, or as ways of reifying the current power structures.

Open expression, with no constraints at all, provides little guidance for audiences, but may help them to develop their own ideas. Strictly closed expressions may provide information for comprehension, but do little to foster meaning making from audiences. Both of these approaches have their place; both are quite useful in many situations. But in science communication, one without the other will not do the work of building the kinds of relationships between scientists, publics, and scientific knowledge sought by practitioners or scholars. Combinations of understanding and interpretation can manifest themselves in any number of ways. Audience members who demonstrated understanding of *Emergence* were able to add to post-show discussions by interpreting the ideas and stories and bringing something new to discussion. Audience members given thematic prompts at the museum were able to develop their own interpretations of concepts like biodiversity, but without more constrained expressions from the presenters, their own interpretations relied more on past exposures to ideas about biodiversity than any expression presented at the time they answered questions for Frontstage. During Gina's presentation, thematic guidance was provided in order for audience members to provide their own expressions, and it was these expressions that were examined by the group for understanding and interpretation.

## **Beyond Engagement: Toward a new Model**

In Chapter 2 I described two overlapping fields in which public engagement is the dominant model for science communication. The first, engagement as exchange, comes from science communication and focuses on developing dialogue between scientists and publics so that scientists are learning from publics just as publics are learning from scientists, and science policies are developed to incorporate the ideas and interests of publics. The second, engagement as interaction, focuses on how practitioners engage publics in informal science learning endeavors, like science center exhibits and programs. Engagement as interaction is focused primarily on creating opportunities for learners to play a role in shaping their learning, often through participatory experiences. I suggest that both engagement as exchange and engagement as interaction models were developed with the idea of explanation and understanding in mind rather than expression and interpretation, and that a reconceptualization in terms of expression and interpretation could drastically reshape both.

A reimagining of engagement as exchange would ask scientists and science communicators to think about creating opportunities for expression and for interpretation among audiences. But it would also incorporate forms of constrained expression in which scientists want to convey explanations that are met with understanding. These expressions would be developed to foster understanding but also to encourage thinking beyond these constrained forms of communication. Similarly, publics would also have or make opportunities to express themselves, likely in both more and less constrained ways. Rather than suggesting there should be a reciprocity, or a fairness or balance between experts and publics, as public engagement does, I suggest that

explaining their work and getting audiences to understand it is but one part of how scientists and science communicators begin to create space for rich interpretations and expressions based on those interpretations.

Typically, expression and explanation still place the creator of the message on one side and the audience for the message on the other side. As we saw with Frontstage, engagement as interaction may involve instances when the expresser and the interpreter are not as clear. At times, the audience was creating the content, and they were expressing themselves for various reason. But the relationship created when they did so was not always a dialogue between the audience and the presenter. There were a number of relationships fostered by different approaches to audience participation that add to the traditional relationships envisioned in straightforward presentations. These relationships are where expression and interpretation play out in a variety of different ways, with different parties in the relationship doing the expressing and interpreting. These expressions and interpretations were constrained in various ways, occasionally becoming explanation and understanding, but often opening space for audience members to interpret one another's expressions, which had their own sets of constraints. This kind conception of engagement as interaction offers a different kind of relationship than science communicators thus far discussed.

A new model of science communication should be based on complex relationships stemming from the possibilities inherent in the expression and interpretation relationships, while paying attention to the dynamics between constrained expressions and interpretation and understanding. Beginning with an examination of these dynamics, scholars and practitioners would be able to



discuss power structures and the balance of power, which play a large role in any kind of science communication, on an individual case basis and in terms of their observations of relationships and of expression, explanation, interpretation, and understanding. Practitioners should advocate for opportunities for mutual expression by both experts and publics, but also for constrained expressions by experts that beg understanding and then open themselves to further interpretation. Similarly, practitioners and publics might seek opportunities for members of the public to create their own expressions, constrained for understanding and open to interpretation, for experts. Scholars should begin to analyze interactions in terms of expression and interpretation, and should pay attention to moments when publics are also asked to express themselves.

The power structures inherent in science and culture will continue to be problematic, and should be discussed as such. But the fact that these kinds of interventions are usually initiated by experts already puts the the public and practitioners on an uneven playing field. A new model for science communication must acknowledge this, and both scholars and practitioners should acknowledge the ways in which the imbalance impacts both expression and interpretation, to recognize how it is built into any attempts to engage either through exchange or through interaction, and to mitigate the imbalance as much as possible. At the same time, a model focused on relationships and expressions would be agile enough that it could provide insight into instances when publics begin the conversation, or other situations that do not resemble traditional power structures surrounding science and publics. For example, it would still be a useful model to consider in instances cases of lay epidemiology or public activism. But while the engagement model focused on the kind of power imbalance that permeates current western cultures, the new model must focus instead on crafting and examining relationships and on expression and interpretation while

remaining mindful of power structures and their impacts. The full development of a new model falls outside the scope of this dissertation; however, future projects will develop the model using expression, explanation, interaction, and understanding as the basis for a model built on the metaphor of an open field rather than a narrow stream.

### **Limitations**

The research in this dissertation yielded important insights and successfully built the case for a new model for science communication. It has also helped lay the groundwork; however, several limitations prevent me from fully developing the new model based on the cases described here. First, this dissertation features work from only three cases, and I play a significant role in shaping each of those cases as a participant observer. The insights gleaned from this research form a valuable lens through which to examine future cases, especially cases in which I am not a participant, but only an observer. However, a lens is not a model or a theory. This body of work points to the need for a new model, and points the way toward one, but more examples of science communication must be examined with the ideas I have developed here in mind. Next steps include more traditional ethnographic observation of science communication endeavors using the lens developed in this dissertation, along with future research through design and participant observation in which I try to intervene and work with ideas for how we might think about the next model of science communication, and how we can evaluate science communication endeavors using ideas from these cases.

The most notable limitation in the examination of art/science collaboration is Itai's participation in both *Dance of Scales* and *Emergence*. Though Itai was an excellent collaborator, he is an

unusual participant in that most scientists are not as willing to take risks professionally by participating in the kinds of project Itai sought with *Dance of Scales* and *Emergence*.

Professional pressure aside, Itai's decision to perform in *Dance of Scales* and his desire to continue performing indicate a unique comfort in front of audiences. Finally, Itai was genuinely concerned that the processes and products of his collaborations were fair. He was far more willing to compromise to maintain that fairness than most scientists. All of this suggests that Itai is a unique participant for a scientist, and that venturing into collaborations with other scientists is likely to reveal a far wider set of relationships between expression and interpretation and between art and science than described here.

The second limitation in these studies is the limited information from audience members in these cases. In *Dance of Scales*, audience interviews were conducted several weeks after the performance, which was interesting in terms of what audiences retained and how they interpreted the performance after time had passed, but they were unable to discuss the performance in any detail. In *Emergence* and in the Frontstage cases, audiences were questioned directly after their participation, but in each of the cases, responses from audiences were somehow limited. In *Emergence*, the questions were part of a post show discussion, and many audience members left before the discussion so the audience members left to answer questions were the self-selected people who wanted to talk or learn more about what they saw. Additionally, answers were given in front of the rest of the remaining audience members, so it is unclear how much the audience members who spoke were performing for their peers. In Frontstage, audiences were often uninterested in answering questions because they felt their participation in Frontstage was akin to

answering questions. There were also logistical issues getting audiences to spend time discussing their experiences.

Ultimately, there will always be issues when trying to research audiences. If they spend more time discussing any experience they have with me than they spent attending the experience in the first place, I learning more about their experiences in answering my questions than their experiences attending the performance. In my future work with audiences, I must strive to ask deeper questions. Now that I have learned so much, questions can be focused more specifically on expression and interpretation, so I will be able to gain real insights through audience ethnography and focused interview and focus group questions.

### **Methodological Notes**

Methodologically, several things about this dissertation were interesting, and merit further consideration. First, I was working within several different fields with different methodological backgrounds. Despite these seemingly unrelated projects, I found strong similarities between participant observation in *Dance of Scales* and *Emergence*, and research through design in *Frontstage*. I treated my work as a participant observer in the two performances as social science endeavors, though they were shaped by my work as a designer and drew heavily on my experiences with Gavers' probe methodologies. In *Frontstage*, I approached the research questions driving the project as a design problem, and developed a research through design agenda, but this work was heavily influenced by my background as an ethnographic researcher. This combination of methods, all inspired by design methodologies and qualitative research design, were effective at driving new ideas and at providing opportunities for understanding

artists, scientists, and audiences. I plan to continue to work in the space between design and research, and to adopt and adapt methods from both areas.

More specifically, I found that research through design as I've envisioned it here has great potential to approach research questions from creative new perspectives, and to gain insight that is likely not otherwise available through conventional research approaches. Thus far, the existing literature on research through design focuses that research within the world of design; however, the cases here present strong examples of the ways design problems and approaches can be used to focus on research questions in other fields. Design approaches like cultural probes were adapted and used to foster collaboration in *Dance of Scales* and *Emergence*, but they also revealed dimensions of the collaborative relationships that might have otherwise gone unexplored. The design problem that drove Frontstage—the problem of how to build an audience participation system that fostered open responses—helped examine the research questions I had about audiences and experts, but beyond helping me find answers, the design problem drove the formation of the questions. Attempting to design for both engagement and assessment drove questions about what I mean by both, and what they had in common. This led to questions about presenters' aims, and to the attempt to build interpretive flexibility into the design. Watching the ways presenters chose to use Frontstage, while at times frustrating, was one of the most illuminating things about all of the research done in this dissertation. Frontstage itself became a research method for me, in addition to a design problem.

This kind of research through design has great potential for future projects for me, and, more broadly, for social scientists with design backgrounds or an interest in design work. I am

suggesting that design methods and design problems be considered not only a path to new ideas and artifacts in the design world, but also a path to new knowledge in broader domains. For example, in order to further develop the new model of science communication I began to conceptualize in this dissertation, I plan to study science making and science hacking communities. I am interested in exploring what motivates people to play with science without expert intervention. Just as I did with the artists and scientists in *Dance of Scales* and *Emergence*, I intend to embrace design methods as a way to explore the reasons and motivations for people who engage in science making and hacking. And then, just as I did with *Frontstage*, I intend to develop a design problem around getting people to engage in hacking and making. Through these design-informed endeavors, I will examine the culture surrounding science hacking and then to investigate how I might intervene to facilitate science hacking among groups of people who do not currently participate.

## **Conclusion**

The projects described in this dissertation were prompted by a desire to better understand the relationship between art and science and between experts and publics. Through the cases, I began to think about interactions between presenters and audiences as a series of relationships among presenter, text, and audience. The relationships are developed through expressions that can be more or less constrained in any number of ways, and which can be interpreted and understood in innumerable ways as well. The use of expression and interpretation as broader categories than explanation and understanding is a concept drawn from the influence of the arts in these cases, and it has deep implications for science communication. Making room for expression and

interpretation as broad categories and then finding the ways expression is constrained creates an approach to science communication that encourages audiences to interpret and make their own meaning from expressions. But constraining expressions and fostering understanding need not be restrictive; understanding can open into new insights and new ways of interpreting expressions. Put simply, explanation need not be relegated to deficit model thinking, but can become a rich part of the experience of participating in, or watching, presentations and making meaning from them.

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